PUMPS

AND

PUMPING MACHINERY.

BY

FREDERICK COLYER, M. INST. C.E., M. INST. M.E.,

CIVIL ENGINEER.

AUTHOR OF 'BREWERIES AND MALTINGS, THEIR ARRANGEMENT AND CONSTRUCTION'; 'HYDRAULIC, STEAM, AND HAND-POWER LIFTING AND PRESSING MACHINERY'; 'GASWORKS CONSTRUCTION'; 'WORKING AND MANAGEMENT OF STEAM BOILERS AND ENGINES'; 'MODERN STEAM ENGINES AND BOILERS.'

PART II.

E. & F. N. SPON, 125, STRAND, LONDON.

NEW YORK: 35, MURRAY STREET.

1887.

PREFACE TO PART II.

In making the additions contained in Part II. of this book, I have added a description of Hand Power Pumps, as suggested by some of my friends, and have selected some important modern types of pumping machinery, many of which, by courtesy of the manufacturers, I have been able to illustrate in the Drawings, Nos. 24 to 34. I have also been able to add further details and data of some of the machinery described in the First Part. I have to tender my sincere thanks to the firms named hereafter for the assistance they have kindly afforded me. Many extra examples might have been given of some of the types now described; it was however considered desirable not to repeat matter when the general principles of working were much the same. I trust the present book will meet with the same kind reception as the last.

FREDERICK COLYER, M. Inst. C.E.
Civil Engineer.

18, Great George Street, Westminster,
November 1886.

CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

LIST OF DRAWINGS.

PUMPS AND PUMPING MACHINERY.

PART II.

INTRODUCTION.

Since the first part of this work was published, it has occurred to the author that several matters of interest might be added; he has included a description of Hand-power pumps, also particulars of several modern pumping engines, notably Deep Mine pumps at Derby, by Messrs. Thornewill and Warham; Blowing Engines by the same firm; Hydraulic Pumping Engines by Mr. E. B. Ellington; Rotary Pumping Dock Engines by Messrs. Hick, Hargreaves & Co. of Bolton, also by Messrs. J. and H. Gwynne; Waterworks Engines by Messrs. Easton and Anderson; sundry Direct-acting Pumping Engines; the Pulsometer and other machines; a description of Messrs. Merryweather's Steam Land Fire Engines and Steam Floats, as well as Force Pumps for Hydraulic Press work; Davey's Patent Motor for driving pumps; and sundry other matters of interest. The leading machinery above mentioned is illustrated in Drawings Nos. 24 to 35.

The author believes most of the chief types of pumping machinery in use in this country are now described in the book, and he trusts the value of the information contained will be much increased by the additions made. He will be much indebted to any one who will favour him with any suggestions or extra detail for a future edition of the book, it being his intention as far as possible to describe at least one type of the most modern kind of pumping machinery at present in use. In the matter now added, in one or two cases, a slight repetition of that published in the first part has been necessary, as he has now been favoured with further descriptions and data of working results by several firms; as the information is valuable, he has taken advantage of the liberality of the firms in supplying it, and trusts that no apology is necessary in pursuing this course. The matter is classified as nearly as possible in the chapters, and as the working results are in most cases given, the reader will be able to compare the machines of the same class, and form his own conclusion as to their respective merits. The author wishes it to be understood, he does not advocate any particular manufacturer's design; he has stated as fairly as possible the relative merits of each machine. All the machinery is modern; the reader will be guided by his own judgment, after making due comparison, which form will best suit his purpose; it was impossible to accept all the kind offers received of drawings, many of which, although valuable in themselves, would have been little more than repetitions of the same class already illustrated. Bearing in mind the original intention of the book, to be a help to those who have to design or order such work, he thinks this will be fully carried out, as he has not only described in detail, but in nearly all cases he has named the manufacturers of the machinery described.

The author once more ventures to advise his readers, when they are about to specify for pumping work, to give very close details not only of the work required to be performed by the machinery, but also the general design and dimensions of the various parts; he will find that it not only gives more confidence to the firms whom he may invite to tender, but puts them on a uniform and fair basis in making up their estimates.

CHAPTER I.

PUMPS WORKED BY MANUAL AND ANIMAL POWER.

HAND-POWER PUMPS may be divided into two principal types, "Lift" and "Force," the former of which will be first treated; "Lift pumps" are used for domestic and other purposes, and although much modified in some details, the principle is the same in all; they are made both close and open at the top; the common type of pump used for contractors' purposes, for clearing water out of foundations, emptying cesspools, &c., is constructed as follows:—

The barrels are made both in wrought and cast iron, at the bottom of the pump a suction valve is provided, this is made of leather closing on a seat of iron or wood; the bucket is made of wood or iron, the exterior being fitted with a cup leather, a valve of metal or leather is provided in the centre of the bucket; for rough purposes no foot valve is provided. A connecting rod is attached to the bucket, and by means of a pin at the top end the working handle is connected; the fulcrum of the handle is fixed to the top of the pump barrel. These pumps are made in various sizes from 3 inches to 6 inches diameter; a superior pump is made with double cast-iron barrels, having one valve box at the bottom, and one delivery spout at the top, a double lever vibrating on a centre fulcrum is used to work the pumps; four or more men are required to work them.

COMMON CAST-IRON PUMPS.—These are for pumping out sewage, or other like purposes, also for roadside pumps; the barrels are cast iron, the buckets are packed with leather, and are also cast iron, they have a central valve the same as those named above, in the better kind, foot valves are provided. At the top of the barrel a spout is formed; the cover of the barrel is separate and is either loose or bolted on; these pumps deliver the water at the top, through the spout.

For Domestic Purposes, pumps are fixed upon a board, the barrels and valves are either cast iron or gun-metal, the barrels are bored out and are closed at the top, a foot valve is provided at the bottom; the bucket is made of gun-metal packed with leather, and has a clack valve, also of leather. The pump rod is copper; it is attached to the bucket by the end, which is screwed into a bridge on the bucket, it works through a gland and stuffing-box in the cover, and to keep the rod parallel in working it passes through a guide which is fixed to the board. At the top of the barrel a passage is provided communicating with a chamber, in which is a delivery valve of the clack kind; the delivery pipe is fixed on top of the chamber. Bonnets should be provided at the valves for the purpose of examination and repair. As the bucket rises and exhausts the air under it, the suction valve opens and the water fills the barrel, at the down stroke of the pump it closes the lower valve, and at the next up-stroke the valve in the bucket closes and the water is lifted through the delivery valve placed at the top of the pump; this top valve also acts as a retaining valve to keep the delivery pipe full while the next down-stroke of the pump is made.

The bucket is worked by a hand lever attached to slings or connecting links, jointed at the lower end to the pump-rod. Water cannot be drawn from a greater depth than 25 to 26 feet below the suction valve of the pump, the height raised by these pumps does not usually exceed from 10 to 20 feet above the delivery valve.

There are many modifications of this class of lift pump, but as the principle is the same in all, no further detail need be entered into; as the pumps are fixed complete on a board they can easily be moved and made ready for work. They are usually made in sizes from 2 inches to 3½ inches diameter; 2½ inches to 3 inches diameter barrels are the most convenient sizes for house purposes. In cases where the water has to be raised above the top of the pump an air vessel is provided, this is for the purpose of affording an even flow in the delivery pipe. The pumps must be firmly fixed to a wall or strong timbers, especially when water has to be lifted much above the delivery valve. At large establishments it is convenient to work pumps of this kind by small windmills; they are in this case placed where the wind can have access to the sails of the apparatus; the pump may be some distance from the well or reservoir from which the water is to be raised, provided that the vertical depth of the water is not more than about 25 feet below the suction valve of the pump; the horizontal distance makes no difference if the pipes are placed slightly on the *ascent* to the pump, and the joints of the pipes are tight.

Hand-power Well Pumps.

For pumping from wells, when the depth of the surface of the water is more than 25 feet from the suction valve of the pump, it is necessary to sink the barrel in the well to a sufficient depth to insure that the lowest level the water is likely to fall to will not exceed 25 feet below the suction valve.

When the depth of the water is not much, a working barrel, provided with valves as before described, is fixed to cross timbers in the well; at the bottom of the barrel pipes are bolted for the suction, and at the top flange sufficient pipes are provided to reach the top of the well where a cast-iron standard pump may be attached, with handle, &c., as before described.

For shallow wells one, two, or three pumps may be fixed at the surface of the ground; they are attached to cast-iron side frames, which are bolted to timbers, and are provided with crank shaft and fly-wheel. When the height to be lifted above the well is small the fly-wheel may be attached direct to the crank shaft, but when the lift is heavy the fly-wheel is attached to a separate shaft, on which is keyed a spur pinion; this works into a spur wheel, which is keyed on to the crank shaft; the proportion of the wheels is regulated by the work to be done and the number of men employed to do the pumping. The construction of the pumps in all these cases does not differ from the hand pumps described on the first part. When pumping any height above the pump barrel, an air vessel should be fitted in the delivery pipe, the water being forced into this vessel compresses the air in it, and so insures a more equal flow of water at the top of the delivery pipe. When raising water any height it is advantageous to use either two or three pumps combined, the delivery is thus made more equal; each crank is set at an angle with the other so that dead centres are avoided; this is especially the case with three pumps, as the circle described by the crank pins is divided into three; no shock takes place in this case as the valves of each pump open and close at different times.

Well Pumps worked by Horse and Cattle Gear.—When the depth of the well is great, and the quantity of water to be delivered is large, a set of three pumps should be fixed in the well, attached to timbers or girders; the pumps have valve boxes at top and bottom; one suction pipe is attached on the under side of the lower valve box, and one delivery pipe at the top box, an air vessel should be fixed close to the top box. The pump-rods are guided in the well by means of rollers which are fixed to cross girders; and near the top of the well the rods are attached to connecting rods with forked ends, the upper ends of which work on to the pins of the crank shaft. The pump-rods in the well are sometimes made of wood, strapped with iron at the ends, they are very light, and last a long time. The top gear consists of a three-throw crank of wrought iron, running in plummer blocks bolted to a cast-iron frame, which is firmly secured to the brickwork at top of the well; on the end of the crank shaft a bevel-toothed pinion is keyed, this works into a bevel wheel keyed on to a vertical spindle. The tooth-wheel gear is carried on either a wood or iron frame, on which bearings for the shafts and spindles are provided. At the top of the vertical spindle a long arm, made of wood or iron, is attached, and at the other end of the arm a yoke working on a pin or swivel is provided, and to this the horses or oxen are harnessed. In cases where the work is heavy, two or more arms are supplied, they are connected at the outer ends, and thus form a large wheel. Another way of applying horse power is by using a large vertical wood wheel; the horse (or donkey) works *inside* the wheel, the interior rim of which is provided with narrow strips of wood, forming treads for the animal's feet. In some cases the horse wheel is keyed direct to the pump shaft, and in other cases it is connected by spur-toothed wheels; the "yoke" system is most generally used. There are several slight modifications of horse gear; they are not, however, of sufficient importance to notice in detail.

CHAPTER II.

DIRECT-ACTING STEAM PUMPS.

THE "DEANE" PATENT STEAM PUMP (Drawing No. 24).—This pump is constructed by the Pulsometer Engineering Company, it is both useful and efficient, it is direct acting, the steam cylinder is made in the ordinary manner, the valve motion, which will presently be described, is peculiar to this pump. The piston-rod is also the pump-rod, a tappet arm is keyed to the rod for the purpose of actuating the steam slide valve, the pump is double-acting, and is either fitted with indiarubber, leather, or gun-metal valves, according to the circumstances of the case; the first named is, however, more generally used; the barrel of the pump may be lined with gun-metal. A large air vessel of the usual kind is provided. The valves and other parts of the pump are easily accessible; this is a great consideration, especially with regard to examination or removal of the valves and seats. The pump is self-contained and compact, it has two feet, and by these it is secured to the foundation stone.

The steam valve, and motion to work it, are constructed as follows:—The tappet arm A is keyed on the piston-rod; as it moves it comes into contact with the collar B when near the end of its motion, and by means of the valve-rod C moves the small slide valve, which operates the supplemental piston valve D. A supplemental *piston carrying with it the main valve* is thus driven over, and the engine is reversed; if, however, the piston *accidentally fails to be moved,* or is not moved promptly by the steam, then the lug E upon the valve-rod strikes it, and *compels* its motion by direct power from the engine. It will be seen that this pump has an additional safeguard, in case the supplemental piston should set fast from neglect or any other cause;

the valve motion is so sensitive, that there is no danger of the pump centering, even if only working at a speed of two or three strokes per minute. All parts move upon parallel lines in the same vertical plane. Both the main and supplemental valves are flat in shape; they are easily re-seated in case of wear. The connection between the main piston and its valve renders it absolutely certain that the valve shall always lead the piston, so that there is no possibility of striking the cylinder covers at either end.

For supplying feed water to boilers these pumps are most efficient; they can be worked at a speed of 2 or 3 strokes per minute, or at 60 or 70 strokes; they are *absolute* in action, cannot fail to start, and are on this account perfectly reliable for such work. The author does not advise the use of any kind of steam pump where the method of working the steam slide valve of the cylinder is not *absolute.*

These pumps are made in sizes from 3½ inches diameter steam cylinder, and 2 inches diameter water cylinder and 5 inches stroke; this size will pump 800 gallons of water per hour. The largest size has a steam cylinder 24 inches diameter, and a water cylinder 18 inches diameter by 36 inches stroke; when working at a speed of 34 strokes per minute, it will pump 60,000 gallons of water per hour; the size of the suction and delivery pipe in the latter case is 12 inches diameter.

THE "DEANE" PATENT DOUBLE PLUNGER SINKING PUMP (Drawing No. 25).—This machine is made by the Pulsometer Engineering Company; it is specially designed for pumping water when sinking wells. The steam cylinder is constructed in much the same way as in the "Deane Pump" (see p. 7); it is fitted with piston valves, which *separately* control the *up* and *down* stroke of the piston, as may be required by the variations in duty. The piston rod of the steam cylinder is attached to a strong lug cast on the side of the upper barrel, the lower part of which carries the second plunger; it will thus be seen, the upper barrel and lower plunger move, while the lower barrel and upper plunger are fixed. The plungers in each case are hollow, and through them the water is discharged. The pump is fitted with two plungers, the stuffing-boxes in each case are placed at the upper end, thus permitting the grit to fall *away from* instead of *towards* the packing; this is a great advantage and saves much wear and tear. There are only two water valves, both of which are accessible by hand doors provided at these points. A very small space is taken up in the well or shaft by these pumps. The water is forced up the pump through its several parts in almost a direct line, thus saving all friction incident to intricate passages.

The power of controlling the stroke of the pump is peculiar to this design; it is unique of its kind, very ingenious, and in working most convenient. The whole machine can be suspended in a well or shaft by means of a chain, and the steam carried down by indiarubber hose.

The steam and water cylinders are held apart by four wrought-iron rods. The moving part of the pump is from A to B; the delivery valve *moves* with this part, but the suction valve at C is *stationary;* the lower plunger D *moves* with the part A B, but the plunger E is *stationary.* The valves of the pump are indiarubber, they are kept up to their work by spiral springs, the seats are gun-metal. The displacement of the lower plunger is twice that of the upper one. The pumps throw a constant stream, and their portability, also the facility with which they can be fixed, renders them a most useful pump for employment for clearing water when sinking wells, or shafts, or for coffer-dam work. There are also many other purposes for which they can be used, especially in any case of temporary deep pumping.

A machine with a steam cylinder 10 inches diameter by 16 inches stroke, and one 7 inches diameter and one 5 inches diameter plunger, will throw about 4500 gallons per hour 150 feet high, when working with steam at 55 lbs. per square inch.

Duplex Pumping Engine (Drawing No. 26).—This is made by the Pulsometer Engineering Company. It is constructed in sizes with steam cylinders from 4 inches diameter by 6 inches stroke to 30 inches diameter by 24 inches stroke. The steam cylinder is made in the same way as an ordinary engine cylinder, except that the passages to the end of the cylinder are made double; the slide valve is the ordinary D shape, secured to the screwed rod with nuts at each end. The double passages are for separate steam and exhaust to the end of cylinder. The exhaust port terminating a short distance from the cylinder end causes an amount of steam to be shut in sufficient to form an efficient cushion. The pump and the valve boxes are cast in one piece, it is double-acting. It will be seen on reference to the Drawing (No. 26) that the barrel chamber is divided into two parts, and at this division a long boss is provided, which may be bushed with gun-metal. The piston-rod is attached to a hollow pump plunger, also divided at the centre. The valves and seats are so simple, they do not require much description; they are made of indiarubber, and are kept up to their work by spiral springs on top of them; bonnets are provided for the examination and easy removal of the valves and seats. It will be seen the general construction of the pump, valves, and chambers is quite free from complication. The piston and pump-rod are in one piece, the steam cylinder and pump are held apart by two side frames; each piston rod has a lever keyed on to it, and by its means the steam valve of the opposite cylinder is worked by the long levers and rocking shaft. The engine can be started at any portion of the stroke, as it is never on a dead centre. The one piston gives steam to its neighbour, and when its stroke is finished it waits until its valve is acted upon before it can move; this gives a pause, and allows the valves to return to their seats. One great advantage of double pumps is, the motion is more regular, the stream of water delivered is more constant, and the pump is free from the shocks that often take place with single-cylinder pumps.

These engines are also made in the compound form when of large size; they are economical in the steam used, and compare favourably with any other engine of the direct-acting type.

They are a very compact form of engine, are simple in action and can be driven by any ordinary attendant, they may either be worked at a low or a high speed, and with a moderate pressure of steam. The method of construction has had careful attention, all parts can be readily got at, examined, removed, or repaired; the passages of the pumps are ample in size and free from sharp bends or curves, and are thus not liable to be stopped in case anything gets into them with the water. It must be borne in mind, no pumps of the direct-acting class can, for economy, be compared with the fly-wheel type of engine used for heavy water pumping; there are, however, many cases where these engines can be applied where the former kind are not admissible.

A great advantage possessed by the Duplex engines is their extreme simplicity: they have few working parts, and there is very little that is liable to get out of order.

A Duplex pump with steam cylinder 14 inches diameter and water plungers 7 inches diameter by 10 inches stroke, working at a speed of 60 strokes per minute, will discharge 9000 gallons of water per hour, the size of the suction and delivery pipes in this case being 7 inches diameter.

THE WORTHINGTON STEAM PUMP.—These are duplex pumps: there are two steam cylinders and two water cylinders. The piston-rods and the pump-rods are in one piece. The valve motion of each of the steam cylinders is worked by means of a crosshead keyed on the piston-rod. No fly-wheel is used. The construction of these pumps is as follows:—Taking an average size low service pump with steam cylinders 9 inches diameter, the diameter of the plungers of the pump is 8½ inches, the length of the stroke is 10 inches; the maximum number of strokes per minute is 100, at this speed both pumps will deliver about 400 gallons of water per minute. The steam cylinders are placed side by side; their construction does not much differ from an ordinary engine cylinder; the slide valves are placed on top, and are the same as the common D slide; the slide rods are connected to the slide valves, and pass through stuffing-boxes in the usual way. A casting or distance piece connects each pair of cylinders and pumps, and in the centre of each a bracket is provided carrying a rocking shaft, short levers are keyed on these shafts, and by means of links are attached to the slide-valve rods; at the other end of the shafts a long lever is keyed, this is connected to the crossheads on the piston-rods by means of links. The movement of the pistons in the two cylinders is made alternately, except that before the finish of the backward or forward stroke of the piston the other one commences moving in the opposite direction; the pump can thus be started at any position of the pistons. The pumps are double acting. The plungers work through deep metallic packing rings. The suction pipes enter a chamber on the under side of the suction valves; the water is discharged through the delivery valves into a top chamber, and thence to the rising main. The valves are indiarubber working on gun-metal seats, and are kept up to their work by brass springs; bonnets are provided, both at the suction and delivery valves, to examine and remove them if necessary; the valve seats are screwed into the pump casting. The alternate motion of the pump plungers gives time for the valves to seat, and thus saves vibration and noise in working. For large sizes the steam cylinders are made upon the compound system; the piston rods pass through from the high-pressure to the low-pressure cylinder direct to the pump plungers.

The pumps can be worked with steam from 15 to 20 lbs. per square inch and upwards, and are capable of pumping water from about 15 to 20 feet below the suction pipes, and discharging it up to 90 feet to 100 feet above the delivery valves.

These pumps are also used for waterworks pumping under heavy heads, they have been extensively employed in America, and have lately been introduced into England; the manufacturers claim that they can pump as economically with them as with the highest class of compound engines made by the best firms in this country. As the author's experience of their performance for heavy pumping is limited, he is unable at present to give an opinion upon the matter.

Duplex Pumping Engines (Drawing No. 27).—This form of engine (originally the Worthington engine) was introduced into this country by Messrs. Easton and Anderson—or rather Easton and Amos as the firm was then called—more than thirty years ago, and is very suitable for certain purposes where it is desirable that the starting and stopping should be effected automatically in accordance with the varying demand for water. This is done by the arrangement of valve gear peculiar to this form of engine.

The engine consists of a pair of horizontal cylinders placed side by side, each working a pump direct by a prolongation of its piston-rod. The slide valve of each cylinder, which is of the usual form, is worked by means of a lever from the piston-rod of the other cylinder. There is practically no lap on the slide valves, the result of which is that there is no dead centre except when both pistons are carefully put at half stroke, a position which they can never both assume simultaneously in practice.

Messrs. Easton and Anderson fitted engines of this type a good many years ago for the water supply of the town of Wisbech, where they are placed several miles away from the town, and pump direct into the mains without the intervention of a reservoir. They have also erected these engines for the water supply of the town of Lymington, Hampshire, where the distance of the pumps from the town is not so great, and where there is a reservoir, though the pumps have frequently pumped into the town mains direct. They have also fitted these pumps for numerous small water supplies to towns, &c.

Another useful application of them is for high-pressure pumps for hydraulic presses and riveting machines, for which purposes the firm have successfully applied them for pressures up to 2 tons per square inch; but the principal use they have made of them has been in connection with hydraulic lifts. These duplex engines and pumps are particularly useful in such cases because they occupy very little space, are extremely simple in construction, and require very little attention. The long experience the firm have had with these engines has enabled them to perfect the details so well, that they will continue working for long periods without requiring any repair. One of the latest forms of these engines is shown on Drawing No. 27.

The most notable recent application of these pumping engines is in the present year (1886), that for the large hydraulic passenger lifts of the Mersey Railway being the largest yet erected in this country. In this case, the pumps raise water into a tank placed on top of the building, over the lift wells, whence it flows to the lifts, but for many months after starting them (before the tanks were ready), the water was pumped direct into the cylinders of the lifts and the service was performed in a most efficient manner. The author has had the pleasure of inspecting the work in operation and can testify to its perfect working.

THE PULSOMETER.—This is a very useful apparatus. It is made by the Pulsometer Engineering Company, and is used for pumping water for temporary purposes, such as in well-sinking, removing water from excavations, and other like kind of work, also for railway and steamship purposes. It can either be fixed to timber or any kind of foundation, or it can be suspended by a chain, and raised and lowered as required.

It will draw water 15 feet below the valves, and is capable of raising it a maximum height of 90 feet. The length of the *horizontal* suction or discharge does not affect the working of the pump if the pipes are of sufficient size to prevent undue friction. When the apparatus is suspended by a chain, the steam to work it is carried down through an indiarubber hose; no exhaust steam pipe is wanted. It will work under water; this is not however advisable if it can be avoided, but still even under these disadvantageous circumstances it performs in an efficient manner. Drawing No. 28 shows a Pulsometer; they are made in various sizes, the illustration is only intended to show the way of construction and working. The body is composed of two chambers with tapering necks bent to a centre neck; the passages terminate at this point in a small steam chamber fitted with one ball valve, this valve oscillates between the two seats, covers are provided at the valves to permit of examination and cleaning. The valves are made of gun-metal or indiarubber, and either as open valves or the grid kind, the work to be done decides the best form of valve.

The pump acts in the following way:—It is filled with water, steam is admitted through the steam pipe K and passes down the side of the neck open to it by the position of the small ball valve, it presses upon the water in the chamber A, and discharges it through the opening and valve into the rising main; when the water is level with the horizontal orifice which leads to the discharge, the steam being brought into contact with the water in the pipes leading to the discharge chamber, instant condensation takes place, and a vacuum is formed in the emptied chamber; the steam ball valve is pulled over by this means, closing the inlet for the steam, and opening at the same time into the other chamber, water rushes in through the suction pipe, lifting the inlet valve, and fills the chamber A again. An air vessel may be placed in the delivery to give a constant flow of water. A foot valve should be used in the suction. The pump does not require any packing, nor any oil or tallow.

The action is very simple, and there is very little to get out of order; there are many cases where it can be used where it would be hardly possible to use any other kind of pump.

The principal purposes for which it is adapted are well-sinking, and also when other pumps break down, also in keeping water clear in coffer-dams and other excavations and draining underground workings. It can also be placed upon wheels and used for irrigation purposes, pumping out sewage tanks, &c. It is used in a large number of steamers for pumping water ballast, bilges, and deck washing. The smallest size will pump 600 gallons per hour, and the largest 65,000 gallons; the size of the suction pipe in the former being 1½ inches diameter, and in the latter 10 inches; the discharge pipes being respectively 1 inch and 8 inches diameter.

The pump has been some years in successful use, and from its portability is a favourite means for clearing water for contractors' and other purposes. It is self-contained, and requires no skill in fixing: it is therefore easily and rapidly set to work, and can be in like manner readily removed when done with.

CHAPTER III.

CENTRIFUGAL OR ROTARY PUMPS.

ROTARY PUMPS.—A pair of these pumps have recently been (1885) put down at Morel's Dock, Cardiff, for draining the dry dock. The work was executed by Messrs. Hick, Hargreaves and Co., Bolton, to whom the author is indebted for the particulars. The engines to drive the pump are of the horizontal type. They work separately, each driving a rotary pump; a large bevel mortice wheel is keyed on each of the crank shafts, and gives motion to a bevel pinion keyed on the vertical shafts, to which the rotary pumps are attached direct. The blades of the pumps are four feet diameter, and run at a speed of 250 revolutions per minute; the ratio of the driving wheels is 2·75 to 1. The engines are horizontal non-condensing, the cylinders being 16 inches diameter by 36 inches stroke. The slide valves are of the ordinary D kind. The speed of the engines is 100 revolutions per minute; the pressure of steam is 80 lbs. per square inch.

The leakage pump is also of the rotary type, with 9-inch inlet and outlet pipes; it is driven by a belt from an oscillating engine fixed at the same level as the main engines. The cylinder of the engine is 10 inches diameter by 18 inches stroke, and the speed 174 revolutions per minute. The boilers to supply steam for the engines are made of steel, of the Lancashire kind, 6 feet 6 inches diameter by 26 feet long, with two 2 feet 6 inches diameter flues. The dock contains, when full, 5,793,867 gallons; the pumps can empty it in four hours. The depth at the centre is 21 feet, and the maximum lift 25 feet. The machinery is contained in a room 37 feet 6 inches by 30 feet. The boilers are in a separate room; space is left for two extra boilers.

The arrangement is very compact, simple in detail, and free from complication. The above statement of work done proves its efficiency.

Direct-acting Centrifugal Pumping Engines.

This machinery was constructed by Messrs. J. and H. Gwynne, of Hammersmith, for pumping the Sandon Dock for the Mersey Docks and Harbour Board at Liverpool.

There are four "Invincible" patent horizontal pumping engines, there is also one 15-inch vertical pumping engine.

The steam cylinders of the large engines are 21½ inches diameter by 24 inches stroke; each is fitted with variable expansion valves. The crank shaft is attached direct to the pump shaft; a fly-wheel works outside the bed plate of the engine, on the reverse side of the pump. The cylinders of the engines are bolted at the end of the bed plate, and overhang. The general arrangement is very compact. The pump propellers are 60 inches diameter.

The work to be done by these engines is to raise the level of the water in the Sandon Dock 5 feet, the dock having an area of 10 acres, and to empty the graving docks, five in number, in connection with the said dock. The contract was to raise 5 feet of water in the dock in three hours, but at the official trial, on March 15th, 1886, this duty was done in 90 minutes. At starting, the height of lift, including friction in the culvert, was 1 foot 11 inches, finishing with a lift of 10 feet 2¾ inches. The leakage during the first 45 minutes of the trial amounted to 1 inch over the entire area of the dock, or 37,085 cubic feet = 231,781 gallons. The diameter both of the suction and the delivery pipes is 36 inches. The average speed of the engines 140 revolutions per minute, the pressure of steam 80 lbs. per square inch, and the average indicated horse-power = 740.

The consumption of coal was 34 cwt. The steam is supplied by four boilers, 7 feet diameter by 26 feet long, of the Lancashire type.

Appold Centrifugal Pumps.

The following particulars regarding the application of these pumps have been given to the author by Messrs. Easton and Anderson since the first portion of the book was written.

WISBECH NORTHSIDE DRAINAGE.—The pumping station is situated close to the "Rummers Sluice," and is erected to assist the drainage of an area of 6632 acres. The machinery consists of a vertical spindle balanced single-inlet centrifugal pump, and a vertical cylinder engine supplied with steam by a single flue Cornish boiler. The fan is 44 inches diameter by 9¾ inches deep, and will deliver 36 tons of water per minute on a mean lift of 13 feet. The pump is placed in a brick well 6 feet 6 inches diameter, and the outlet culvert is provided with a self-acting flap valve to prevent the return of water from the river. A water-tight diaphragm is placed in the well to prevent the water rising in the engine room when pumping against high tide. The fan is suspended by means of an "onion" bearing from a cast-iron beam attached to a cast-iron curb ring on the top of the well, and a bevel pinion is keyed to the fan spindle underneath the cast-iron beam.

The steam cylinder is 18 inches in diameter by 21 inches stroke, it is steam jacketed and lagged, and is placed directly over the crank shaft on a projecting bracket of the bed plate. The piston-rod works through a stuffing box in the top cover of the cylinder on to a crosshead working in guides bolted to the cylinder cover, and from which one connecting rod on each side passes down to the crank shaft underneath the cylinder. The slide valve is worked by an eccentric on the crank shaft between the two cranks through a lever and rods. The air and feed pumps are vertical, they are bolted to the bed plate behind the cylinder and are worked by a beam off the crosshead. The bed plate forms the condenser, and besides the central projecting bracket which carries the cylinder, has two horns projecting forward in horseshoe fashion, to carry the crank shaft bearings. The crank shaft is continued on one side to the cast-iron beam carrying the "onion" bearing of the pump spindle, its outer end resting in a bearing bolted to the cast-iron beam. Between this outer bearing and the bearing on the bed plate, the fly-wheel is keyed on the crank shaft having a bevel wheel. attached to the rim, geared into the pinion on the pump spindle.

The whole forms a very compact arrangement of drainage plant, and works in a very satisfactory manner; it has the additional advantage of being cheap in first cost and economical in working. The normal working speed is 75 revolutions per minute.

CENTRIFUGAL PUMPING MACHINERY.—Another form applicable to situations where the ground is marshy and the foundations are liable to settle, is constructed as follows:—

The pump is driven by a pair of patent horizontal balanced engines, bolted to the top of the pump case itself, the crank shaft being attached by a flange coupling direct to the top of the vertical fan spindle. The engine framing extends beyond the pump case on either side. The low-pressure cylinder is on one side, whilst the high pressure cylinder is on the other; the air pump and condenser are behind, and are worked by the piston-rod; the exhaust pipe from the low pressure cylinder forms the principal part of the condenser. The cranks are opposite each other, and all the moving parts are completely balanced; a small fly-wheel is placed underneath the engine framing to equalise the motion, which is thus made very uniform. The weight of the pump spindle and crank shaft is taken by an "onion" bearing at the upper end of the crank shaft supported by a casting spanning the two engine frames. The whole arrangement is self-contained and independent of the masonry.

A set of machinery of this kind was sent to Demerara in 1883 to replace a smaller plant of an older type. The fan is 60 inches in diameter by 16 inches deep; the cylinders are 13 inches and 22½ inches in diameter respectively, and each 16 inches stroke. It pumps 100 tons of water per minute to a height of 5 feet, the maximum lift for a correspondingly smaller quantity being 9 feet.

DEVONPORT DOCKYARD.—This machinery is for pumping out No. 3 dry dock at Devonport Dockyard, and consists of the following:—

Two patent single inlet centrifugal pumps 7 feet 6 inches diameter by 11¼ inches deep, each driven by a pair of horizontal compound condensing engines placed at right angles to each other, and working direct on to a single crank, connected to the top of the pump spindle. The high-pressure cylinder is 18 inches diameter, and the low-pressure 30 inches diameter, both 18 inches stroke. The weight of the pump fan and spindle is carried by a collar bearing at the top of the pump spindle. The leakage pumps are three-throw, 20 inches diameter by 3 feet 3 inches stroke, and are worked through spur gearing by a double-cylinder horizontal condensing engine, having cylinders 12½ inches diameter by 20 inches stroke. The steam pressure is 80 lbs. per square inch, and the exhaust steam from the leakage as well as the main engines is led into a condenser common to them all; the air pump is worked by the leakage engine. The condenser and air pump are placed in a tank which is supplied with water from the delivery of the leakage pumps, and from which the injection water is taken.

A small steam engine is provided for working the sluices in the culverts.

The capacity of the dock is 39,000 tons of water, and the pumps are capable of emptying it in four hours.

CHAPTER IV.

PUMPING ENGINES.

PATENT SAFETY MOTOR (Drawing No. 29).—This is a new engine of a very simple type, lately brought out by Mr. H. Davey, of the firm of Messrs. Hathorn, Davey & Co., of Leeds, to whom the author is indebted for the drawing. It is applied to a variety of purposes, especially for pumping water for domestic supply, and for schools, &c. The machine is an absolutely safe and reliable motor, and can be worked by any unskilled person; it is more correctly speaking a vacuum engine. A small furnace is surrounded by a water jacket or "kettle," the fuel used may be coke, coal, or wood, which is fed through a fire door, the water in the boiler or "kettle" is boiled as in an ordinary water-heater, steam is raised at the same pressure as the atmosphere, the steam (or vapour) passes direct from the "kettle" to the cylinder, and from the cylinder to a surface condenser, in this a vacuum is maintained by a small air pump; it will be seen that the cylinder is enclosed in the steam chamber, and by this means condensation is prevented. The whole of the machine is attached to a bed plate on which the boiler or "kettle" consisting of a casting is fixed vertically, and in the interior of which the cylinder at the upper part is placed in an inverted position; the piston-rod works through an ordinary stuffing-box and gland. The guide is a small hollow piston or trunk, working in a bored cylinder open at either end, the connecting rod is attached at the centre, the other end works on to a crank shaft, at one end of which is keyed a fly-wheel, and at the other a crank plate to work the air pump which is fixed direct to the casting of the "kettle." An eccentric on the crank shaft works the slide valve in the ordinary way of a common steam engine. The condenser is a separate casting fixed at the back, connected by pipes to the steam space of the boiler, and to the air pump. The air pump extracts from the surface condenser the water formed by condensation, and delivers it into the boiler, so that it is constantly fed with hot and almost pure water, thus preventing any incrustation forming. The feed to the boiler is thus automatic, as are all the other parts of the motor except the fire, this in the self-contained motor now under consideration requires attention about once per hour; the times for adding fuel, of course, will vary with the work on the motor. As there is no pressure in the boiler it is absolutely safe, and even if neglected accident is impossible, it is perfectly reliable in its action and can be usefully employed for pumping and other purposes at private houses or public institutions. Any one can work the engine, there is nothing to get out of order. This class of the motor is made in sizes from one-half to six horse-power.

Another form of the motor is made where the boiler is of the "hopper" kind and is separate; the furnace is constructed to hold six to eight hours' supply of fuel, it requires no attention whatever during this period of time. This class of engine is made in sizes up to 10 horse-power.

For Pumping Purposes.—The crank shaft is extended beyond the fly-wheel, and is made to carry a pinion to work gearing or a belt pulley from which the power is transmitted to the pumps. In the small sizes of motor the pump is driven direct from a crank pin on the boss of the fly-wheel.

The engine when not pumping may drive any kind of domestic machinery, such as washing machines, bread making, or electric lighting apparatus. The pumps if desired may be fixed separate from the engine, and driven by a strap or belt from the rim of the fly-wheel. This is one of the most ingenious and useful engines for small powers that has been introduced for a long time, and fills a want very often felt. It is entirely free from the difficulties that occur with hot-air or gas engines, and is far more economical in working, the cost of which is as follows:—

The test made by the Royal Agricultural Society at Preston, in 1885, showed that the motor consumed a little over 6 lbs. of gas coke per brake horse-power per hour, the trial was made in the open air, part of the time during rain. Later trials have given a consumption of 30 lbs. of steam per indicated horse-power per hour.

The motor being self-contained can be delivered ready for bolting down. It does not require skilled labour to fix it and is admirably adapted for pumping up water to supply tanks for working hydraulic lifts. As these are now coming into use in mansions and other large institutions, the motor may much extend their adoption.

Compound Beam Engines for Waterworks Pumping.

The following are some additional particulars furnished to the author by Messrs. Easton and Anderson relating to the engines already mentioned at pp. 72 to 74 in the first part.

Brighton Waterworks.—There are four engines, constructed at different dates, the first in 1854 and the last in 1874; they are all of the same size, and generally of similar construction.

The bed plate consists of several pieces bolted together, upon which stand two fluted columns; the entablature beam rests on these and spans the engine room, its ends being firmly built into the walls.

The high-pressure cylinder is 28 inches diameter by 5 feet 4¾ inches stroke, and the low-pressure cylinder 46 inches diameter by 8 feet stroke. Underneath the bed plate is an oval well containing two lift pumps 32½ inches diameter and 30 inches stroke, which pump from the deep well into the low-service reservoir at the ground level. From this reservoir a double-acting pump under the beam pumps the water into the high service, whilst another pump (or pumps) worked from the outer end of the crank shaft discharges into the middle service. By this arrangement each engine pumps into each of the three services (high, middle, and low levels) with which Brighton is supplied. The net lifts of the three services are: "low," from well 129 feet; "middle," from reservoir 92 feet; "high," from reservoir 166 feet.

None of these engines are steam-jacketed; at the time the first engines were erected steam-jacketing was little used, even as late as 1867, when the third one was fixed. When the last one was constructed in 1874 it was, unfortunately, desired to preserve uniformity, and thus again steam-jacketing was not resorted to; this is much to be regretted, as there can be no doubt from recent experience that a great economy in working would have been thereby effected. However, some improvement was admitted to the last engine, which was fitted with expansion gear and supplied with steam at 60 lbs. pressure per square inch instead of 45 to 50 lbs.

The third engine was tested in 1872, after five years' work, with the following results:—

Duration of trial	10 hours 35 minutes.
Equivalent evaporation from and at 212° per lb. of coal	10·7 lbs.
Mean steam pressure in boilers	44 lbs.
Mean weight of Newcastle coal per I.H.P. per hour	3·02 lbs.
Mean weight of steam per I.H.P. per hour	28·8 lbs.
Average number of revolutions per minute	13
„ I.H.P.	204·1
Efficiency = $\frac{\text{useful H.P. in water lifted}}{\text{I.H.P.}}$	0·806.

The fourth engine was tested on 13th November, 1877, with the following results:—

Mean steam pressure in boilers	60 lbs.
Mean weight of Newcastle coal per I.H.P. per hour	2·36 lbs.
Mean weight of steam per I.H.P. per hour	21·9 lbs.
Average number of revolutions per minute	16·19.
„ I.H.P.	285.

Thus it will be seen that this last engine worked with considerably greater economy than the previous ones.

The author calls particular attention to the conditions under which these engines were tested, to enable the reader to fairly compare others mentioned in the book, where the circumstances were much more favourable.

Portsmouth Waterworks.—The author has been favoured with additional particulars of these engines by Messrs. Easton and Anderson. At the Havant pumping station there are four compound condensing beam engines of nearly the same size. The first two were constructed in 1859, the third in 1867, and the fourth in 1880; they afford an interesting example of the advantage of steam-jacketed over non-jacketed cylinders.

As in the case of the Brighton engines, the entablature frames are carried upon a pair of columns and their ends are built into the walls of the engine house. Each engine has one double-acting piston pump worked from the beam on the crank side of the beam centre.

The first three engines had unjacketed cylinders, and were worked by steam at 40 lbs. pressure. The last engine is supplied with 60 lbs. steam from new boilers, and has steam-jacketed cylinders with variable expansion gear to the high-pressure cylinder. The cylinders are 27 inches diameter by 3 feet 9 inches stroke, and 38 inches diameter by 6 feet stroke; diameter of pump 20 inches, with 3 feet stroke. The engine makes 22 revolutions per minute, indicating 140 horse-power, and delivering 2376 gallons of water per minute against a total head of 160 feet.

After a few months' experience with this new engine the directors were so satisfied with the economy effected that they ordered similar cylinders and fittings to replace the old ones on the other three engines. The steam pressure was also raised from 40 lbs. to 60 lbs. per square inch, and a second main was laid to the reservoir to reduce resistance.

The result of all these alterations was to reduce the consumption of coal to *one-half* its previous amount, and of this saving fully 60 per cent. is estimated to be due to the improvements introduced into the engines themselves. The alterations to these engines prove the necessity of having machinery well up to modern requirements; the large saving in coal in this instance will soon repay the outlay, added to which the engines perform their work in a far more satisfactory manner.

Lambeth Waterworks, Brixton Hill.—The author has been favoured with further particulars of these engines, described in first part. Drawing No. 30 shows two pairs of beam pumping engines constructed in 1875–6 for pumping 5,000,000 gallons of water per day against a normal resistance equal to about 230 feet head from the reservoirs on Brixton Hill to the reservoir at Norwood. Both pairs of engines are precisely similar in construction, but the later one is rather larger than the first, giving about 25 per cent. greater delivery of water.

The first pair was started in December 1875 and the second pair in February 1877. It will suffice to describe the larger pair of engines; it consists of two single cylinder beam engines, one being the high-pressure and the other the low-pressure, with one crank shaft common to both, with cranks at right angles and the fly-wheel, 15 feet diameter and 7¾ tons weight, in the middle of the shaft. The high-pressure cylinder is 22½ inches diameter and the low-pressure 45 inches diameter, each having a stroke of 5 feet 6 inches.

Each cylinder stands on a strong cast-iron bed plate 23 feet 9 inches long by 5 feet 4 inches wide and 15½ inches deep, bolted to the foundation. A pair of A frames in the centre carry the middle of the entablature, the ends of which are supported by polished wrought-iron columns. At the crank end these columns rise from the bed plate; at the cylinder end they rise from the bed plate of the high-pressure engine and from bosses cast at the top of the low-pressure cylinder. The crank shaft pedestal is bolted on the bed plate, and the beam pedestals are bolted on the top of the entablature.

The air pump is 15 inches diameter by 2 feet 8 inches stroke, giving a capacity per revolution of the engine of about two gallons per maximum indicated horse-power. It is worked by a rod from the beam on the crank side of the low-pressure engine, the feed pump is similarly worked by the high-pressure engine.

The air pump discharges into a tank in the centre of the engine house, from which the feed pump draws its water. The surface condenser is placed between the two engines, the suction water of both pumps passing through it; it has ¾ inch brass tubes packed with wood ferrules, the water circulating outside the tubes; the tube surface is about 2¼ square feet per maximum indicated horse-power. The cylinders are both steam-jacketed and lagged, and fitted with double expansion slides, those on the high-pressure engine being adjustable by hand while working.

The exhaust steam from the high-pressure cylinder passes through a re-heater to the low-pressure cylinder. This re-heater is a cylindrical tube drum placed on an incline rising from the high-pressure cylinder, the exhaust steam passing through the tubes, the casing is supplied with steam from the main steam pipe; this arrangement effects a similar object to the Cowper re-heater, but seems simpler in its details. The condensed water from the steam jackets, reheater, and separator is collected in a central vessel so placed that the feed pump suction water passes through it and mingles with the condensed water on its way to the pump.

The beams are made of wrought-iron plates riveted together, with cast-iron bosses riveted on for supporting the several gudgeons. Lead counterbalance weights are introduced between the beam flitches at the crank ends to balance the pumps.

There is one main service pump to each single engine of the bucket and plunger type, the barrel is 22½ inches diameter and has a stroke of 2 feet 9 inches, it is bolted direct to the under side of the bed plate, and worked off the same parallel motion which guides the piston rod. The barrel is hard cast iron, and the bucket is packed with gun-metal spring rings ¾ inch wide in two grooves, two rings in each groove. The valves are of the annular ring type with three concentric gun-metal rings in each valve, falling on gun-metal seats, and having a heavy cast-iron guard above to regulate their descent. Each pump has also a flap retaining valve in its delivery branch. A section of one of the pumps is shown on Drawing No. 30.

Each pair of pumps draws water from the reservoir behind the engine house through an 18-inch diameter suction pipe, and then through the surface condenser, the two separate suction pipes branching from the top of the condenser to the pumps. To equalise the flow of water as much as possible in the 18-inch main suction pipe, an air vessel is placed on the top of the condenser with a capacity of about 280 gallons.

Steam is supplied by five boilers, placed as shown in the drawing, each boiler is 7 feet diameter by 21 feet 7½ inches long, and has two internal flues 2 feet 9½ inches diameter. Two boilers will supply steam enough for both pair of engines working full speed; but ordinarily three boilers are worked at a time.

The first pair of engines was tried on special high service duty in March 1876, with the following results:—

Average height of lift	321·4 feet.
Mean pressure of steam	59 lbs. per sq. inch.
Rate of expansion in cylinders	8 to 1.
Consumption of steam in cylinders only per I.H.P. per hour	17 lbs.
Number of revolutions per minute	19·44.
Indicated H.P.	156·8.
H.P. water lifted	141·9.
Efficiency $= \frac{141\cdot 9}{156\cdot 8}$	0·905.

On the 18th July, 1877, a trial was made of both pairs of engines working together, when

Height of lift was	225·8 feet.	
Mean steam pressure	54·4 lbs. per sq. inch.	
Consumption of steam in cylinders only	16·7 lbs.	per I.H.P. per hour.
" " jackets	2·75 lbs.	
Total	19·45 lbs.	

The efficiency was 89·85 per cent., thus entirely corroborating the results of the earlier trial; the water in passing through the surface condensers was raised in temperature about 2¼° Fahrenheit, as nearly as could be read on ordinary thermometers.

Antwerp Waterworks (Drawing No. 31).—The author has also been favoured by Messrs. Easton and Anderson with additional particulars of these engines. The pumping station is at Waelhem, about 10½ miles from Antwerp, on the river Nethe, from which the water is obtained. The water is allowed to run into settling ponds direct from the river; it is then run into two pits, whence it is pumped up by two of Airy and Anderson's patent screw pumps to the proper level for passing through Anderson's patent revolving purifiers (filled with spongy iron), after which it is filtered through sand filter beds, and then runs into cast-iron reservoirs, whence it is pumped direct into the mains without interposition of a high reservoir or water tower.

The whole arrangement of the pumping machinery, together with the boilers, is shown in Drawing No. 31.

There are two pairs of compound condensing beam engines, the engines of each pair being coupled together at right angles by a common crank shaft and fly-wheel; they are carefully balanced so that they will creep round as slowly as one and a half revolution per minute, although their maximum speed is 22 revolutions per minute.

Each engine has a continuous cast-iron bed plate, with a pair of A frames in the middle of its length supporting the entablature and the pedestals for the main beam gudgeons; the ends of the entablature are supported by columns on the bed plate. The crank shaft pedestal is cast on the bed plate. The high-pressure cylinder is 18½ inches diameter by 3 feet

8 inches stroke, and the low-pressure one 30 inches diameter by 5 feet 6 inches stroke.

They are both steam-jacketed and lagged; the high-pressure cylinder is fitted with Meyers' variable expansion gear, and receives steam from the boilers at 65 lbs. pressure per square inch. The beams, connecting rods, and cranks are of cast iron, and the crank shaft of wrought iron.

There is one bucket and plunger pump with barrel 22½ inches diameter and 33 inches stroke (delivering 47·3 gallons per revolution), fixed in the brickwork under the high pressure cylinder of each engine, and worked from the back links of the parallel motion. The valves are of the ring type, beating on gun-metal seats. The suction pipe is very short, and dips direct into the clear water sump. Each pump has a self-acting non-return valve on its 12-inch delivery pipe; beyond this the pipes from each pair of pumps unite by a T pipe into one 15-inch pipe, which is connected to the sides of a cast-iron air vessel of 65 cubic feet capacity, placed within the engine house. The delivery pipe then issues from the bottom of the air vessel, and joins the 20-inch main leading to Antwerp; this pipe is also fitted with a self-acting non-return valve. There being four deliveries of water in each revolution of a pair of engines, they work very smoothly, steadily, and noiselessly.

Besides the main pump, each engine has its own air and feed pumps, and each pair of engines has one air-compressing pump for charging the air vessels.

Any engine can be uncoupled, and its fellow can then be worked by itself. The total head of resistance at the pumps is 280 feet; the work done is 1042 gallons of water lifted per minute, and the efficiency is nearly 90 per cent. The screw pumps already mentioned are situated in an annexe adjoining the engine house. They are 3 feet diameter by 42 feet long, placed at an angle of 30° for a maximum lift of 19 feet, and are capable of delivering 2000 gallons per minute. This type of pump has been described in first part on page 36. Advantage is taken of the property of these pumps of accurately measuring the water they pump, to keep a record of the quantity of water raised daily into the filters. Each pump is driven by a separate 12 horse-power horizontal non-condensing engine; the exhaust steam from these engines passes through the spiral coil of a feed heater, and is almost entirely condensed in heating the feed water for the boilers.

The boiler house is on the other side of the engine house, it contains four double-flue multitubular boilers, constructed for a working pressure of 65 lbs. per square inch; each boiler is 6 feet 6 inches diameter by 23 feet long, and has two 2 foot 6 inch flues terminating in thirty-seven tubes 3 inches diameter, and 6 feet long. Each boiler is capable of evaporating 50 cubic feet of water per hour from 100° Fahrenheit, at 65 lbs. per square inch pressure. They are set in brickwork with split draught round the sides, and a return flue underneath.

Sutton Waterworks.—This is an example of a self-contained compound condensing beam engine, working three bucket and plunger pumps direct from the beam, each pump supplying a separate service under a different head of resistance, but all three pumping from the same well.

The high-pressure cylinder is 18½ inches diameter by 3 feet 8 inches stroke, and the low-pressure cylinder 30 inches diameter by 5 feet 6 inches stroke. The low service pump barrel is 18 inches diameter by 33 inches stroke, it has a capacity of 650 gallons at 22 revolutions per minute, and pumps against 182 feet head. The middle service pump is 12 inches diameter by 36 inches stroke, with a capacity of 325 gallons per minute, and pumps against 291 feet head. The high service pump is 14 inches diameter by 16¾ inches stroke with a capacity of 200 gallons per minute, and pumps against a head of 526 feet.

The pipes and connections are so arranged that any pump can be shut off without stopping the others, and also that any pump may be put on to any of the three services, although usually all three pumps work together, each on its own service.

The engine is fitted with a surface condenser, with a circulating pump worked direct off the beam, the air pump is worked by the continuation of the low-pressure piston rod through the bottom of the cylinder.

The whole arrangement is very compact and strikingly illustrates the advantages of a beam engine for performing such various services with a single motor.

Winchester Waterworks.—Compound Beam Pumping Engine and Well Pumps, erected by Messrs. Easton and Anderson

(Drawing No. 32).—It differs from those before described in so far as it is made to actuate two deep well pumps. The engine is one of their self-contained double-cylinder beam engines, with cylinders 17 inches diameter by 4 feet 1¼ inch stroke, and 25½ inches diameter and 5 feet 6 inches stroke, bolted to the bed plate, which carries two A frames in the middle of its length, supporting the beam, and two columns at each end, on which rests the entablature. The beam is made of wrought-iron plates with cast-iron distance pieces. The high-pressure cylinder is fitted with variable expansion gear, adjustable by hand whilst the engine is running. The engine works with steam at 60 lbs. pressure per square inch, expanding eight times, and making 25 revolutions per minute.

There are two single-acting lift pumps worked by rods direct from the beam, one on either side of the centre, each 16½ inches diameter and 2 feet stroke. They are placed in a well of oval shape, 7 feet by 5 feet 6 inches; it is situated under the centre of the engine, and is 175 feet deep. The pump clacks are about 25 feet above the bottom of the well, or 150 feet below the surface, they are united by a breeches pipe below the clacks from which depends a single suction pipe.

On the delivery side each pump is fitted with a bend and self-acting non-return valve; a breeches pipe connects the deliveries of these self-acting valves with the bottom of an air vessel. The rising main dips down to nearly the bottom of this air vessel, and then rises to the surface.

The pumps are supported on two strong cast-iron girders built into the sides of the well, which also carry the weight of the pipes.

At intervals of about 18 feet cast-iron girders are built into the sides of the well, to which are attached guides for the pump rods. The rising main is clamped to these girders, which also carry timber landing stages or platforms; and wrought-iron ladders are fixed from stage to stage so as to give ready access down the well.

At the normal speed of 25 revolutions per minute of the engine these pumps deliver 900 gallons of water per minute against a total head of resistance, including the suction, of 175 feet.

Compound Pumping Colliery Engines at the Denby Colliery, Derbyshire. (Drawing No. 33.)

These engines were designed and manufactured by Messrs. Thornewill and Warham, Burton-on-Trent. They are fixed underground at a depth of 169 yards; they are of the horizontal type; there are two separate engines, but coupled by one crank shaft and fly-wheel. The low-pressure cylinder is 54 inches diameter by 48 inches stroke; it is fixed on one bed plate, and the high-pressure cylinder, which is 20 inches diameter by 48 inches stroke, is on the other. The cylinders are arranged in the marine fashion, with the high-pressure valve chest on the outside, the exhaust being delivered through a belt into the low-pressure steam chest between the cylinders having sufficient capacity to form a receiver. The low-pressure steam-chest cover is on the end of the cylinder; neither cylinder is steam-jacketed. The low-pressure cylinder is fitted with a starting valve, and the high-pressure with warming cocks and pipes. A pump, 10 inches diameter by 48 inches stroke, is fixed at the back of each cylinder; the pumps are double-acting; the valves and seats are double-beat and made of gun-metal with flat faces, they are 12 inches diameter, and are held down by screw bolts and cross bars in the valve boxes. The plungers are cast iron, fitted with a steel through rod, and secured by nut securely pinned.

There are four air vessels upon the suction pipes, and one in the delivery main, fitted with Wipperman's air injector. The high-pressure cylinder is fitted with variable expansion gear; the low-pressure cylinder has a double-ported slide. The air pump and condenser are placed at the crank end of one bed plate; the pump is 14½ inches diameter by 48 inches stroke, it is double acting. The connecting rods are wrought iron, fitted with strap ends at the crossheads, and solid marine ends at the crank pins. The crank shaft is wrought iron, 10 inches diameter in journals, 11 inches in body, and 12 inches at the wheel seat; the fly-wheel is 15 feet diameter by 8 inches wide, and weighs 10 tons.

The steam pipe is 8 inches diameter; the eduction pipe to the condenser is 14 inches diameter. The suction pipes of the pump are 10 inches diameter, and the delivery main 15 inches diameter.

The engines, when running at 20 revolutions per minute, are capable of delivering 800 gallons of water per minute 510 feet high; if run at a higher speed in case of emergency they will deliver 1000 gallons per minute. The cylinders are firmly secured to the bed plates by bracketed feet and turned bolts and nuts, the covers are made sufficiently deep to form the piston clearance, the cylinder castings being just long enough for the working bore; the glands and stuffing boxes are bushed with gun-metal, the cylinder covers are fitted with spring relief valves. The piston rods are of mild steel, the couplings at the pump end being cast steel; the cross heads are of wrought iron. The guide bars are fitted to stays, and so arranged that both the top and bottom bars can be adjusted to any wear of the guide blocks.

The air pump is fitted with a piston having three packing rings, the foot and head valves are indiarubber; the injection valve is of the "gridiron" type, the valve and seating are made of gun-metal, a suitable hand gear is placed conveniently for the attendant. The condenser is fitted with internal spray pipe under the exhaust inlet, and is fitted with a snifting valve for draining it.

The bed plates are made in suitable sections for getting down the pit, the joints being planed and secured with turned bolts and nuts. The pistons are of cast iron, box section, fitted with Oldham's patent rings, the junk rings being secured by T-headed bolts and gun-metal double nuts, instead of using a check ring. The eccentric rods are of wrought iron fitted with steel pins; the valve spindle ends being fitted with gun-metal bushes, secured by wrought caps and bolts. The low-pressure valve gear has a radius link fitted so that the cut off may be altered if necessary.

Diagrams were taken soon after starting the engines (in the early part of 1886), they were then running at 20 revolutions per minute, the pressure of steam being 49½ lbs. per square inch, and the vacuum 26¼ inches; the head of water pumped was 506 feet, equal to a pressure of 220 lbs. per square inch. It may be remarked that 20 revolutions per minute is found quite sufficient for the present work; the engines have been run up to 32 revolutions per minute for a considerable time without in any way interfering with their smooth and efficient working. At the time the diagrams were taken the steam cylinders and the pipes which were fixed in the downcast shaft were not clothed, hence much condensation of steam took place. Since then the pipes and steam cylinders have been clothed, the boilers have been worked at a higher pressure, thus enabling the grade of expansion to be increased in the high-pressure cylinder; no diagrams have been taken when working under these conditions, or a higher result than that given above would be shown. It should also be borne in mind in comparing these engines with ordinary pumping engines placed *above ground*, allowance must be made for the difficulties met with in the former case which do not arise in the latter. The difficulty in procuring dry steam, in the case of underground engines, is much increased; the condensed water to be got rid of is also a much more difficult matter than in the case of ordinary engines.

The total weight of the engines and pumps, exclusive of pipes, is 85½ tons. The author believes these are the largest underground colliery pumping engines in England, their design and efficient action reflects much credit on the manufacturers.

CHAPTER V.

HIGH-PRESSURE PUMPING MACHINERY.

FORCE PUMPS FOR HYDRAULIC PRESSES.—These pumps are specially constructed for pumping water under heavy pressure into hydraulic presses, they are usually made of gun-metal or of phosphor bronze; the plungers are made solid and either of gun-metal or steel; the barrels are bored out the whole length, the valve boxes are made of gun-metal, the valve chambers and the passages connecting them are bored out by machine. The diameter of the pumps varies from $\frac{3}{4}$-inch to 3 inches diameter; for working one or two presses, one pair of pumps fixed on a cistern containing water or oil is used, one pump being $\frac{3}{4}$-inch to $\frac{7}{8}$-inch diameter, and one $1\frac{1}{2}$-inch or 2 inches diameter; the stroke of the pumps is usually about 3 inches; one delivery valve box serves the two pumps, a safety-valve and graduated weighted lever is also fitted to the valve box. The suction valves and pipes are placed immediately under each pump; the end of the pipes are provided with copper roses drilled with fine holes. The plungers are made with an open or double joint, and through this the working levers pass and are attached by steel pins; the top ends of the plungers work through bushed holes in cast iron bridges; these bridges are bolted to the tank, and have lugs cast on one side for the fulcrum-pins of the working lever, at the other side they are made open for the levers to pass through and so form guides for them.

The working levers are usually made rather short, and finished with square ends; when the pumps are to be worked by hand-power, long levers with sockets at one end made to fit the ends of the short levers, are provided. If the pumps are occasionally to be worked by steam power, eccentrics and rods are employed; the ends of the short levers are drilled with holes and at any of these points the pins of the eccentric rods can be passed through. A pressure-gauge is attached to the valve box to show the pressure attained; the working pressure varies from 1 ton to 3 tons per square inch, in some cases for special purposes a higher pressure is used. For information as to hydraulic presses and further details of pumps, both for small and large purposes, see the author's book upon 'Hydraulic Lifting and Pressing Machinery,' E. and F. N. Spon, London.

Hydraulic Press Pumps Worked by Steam Power.

When only one or two hydraulic presses have to be worked the above plan is usually adopted, the power being obtained from any convenient shafting; in cases where a large number of presses have to be worked, separate engines are employed and the pumps constructed upon a much larger scale; they are made in sets of six, and 1-inch and 1¼-inch diameter by 3 inches stroke; the plungers, barrels, and valve boxes are of gun-metal and made in much the same way as before described. The pumps are fixed to a cistern or tank, to this side frames are attached carrying bearings at the top, or columns and entablature may be used; in the bearings a wrought iron or steel shaft works, which is either made in the form of a crank shaft or has solid "cams" forged on it; it is made 3 inches to 3½ inches diameter, and the bearings 4 inches to 4½ inches long, they are usually placed on the *underside* of the side frames or entablature; this is for the purpose of taking the thrust off the caps of the bearings. The connecting rods are made very strong, about 1¾-inch diameter at the ends to 2¼ inches diameter at the centres; they should be made of steel, the ends working on the crank-pins are made of gun-metal. The pressure pipes are wrought iron ¾-inch diameter and are connected to main pipes 1-inch diameter, not more than twelve pumps go into one main. In large establishments twelve pumps are used to put on the pressure to 20 cwt. per square inch, six are then knocked off by automatic gear and the full pressure of 50 to 60 cwts. per square inch is put on; safety valves are arranged to relieve the pumps when the full pressure is obtained.

The speed of the pump shaft is from 60 to 70 revolutions per minute; nothing is gained by working at high speeds, owing to the "slip" that takes place through the pump valves. The pumps should have double leather "hat-shaped" packings; these must be made of the very best oil-dressed leather, cut out of the middle of the back; these leathers should always be put in by skilled men and if the water is kept clean they will last a long time.

The pressure pipes should be Perkins' patent high-pressure wrought-iron pipes, the threads at the joints should be cut in a lathe. Safety valves should be placed in the main pipes to relieve the pressure on them in case of a stoppage in any direction. The valves used at the presses are a very special kind, and must be made out of solid gun-metal and be of the highest character; Messrs. Bellhouse and Co., of Manchester, make some of the best valves for this purpose. The water in the tanks of the pumps should be kept very clean, and perfectly free from grit; in some cases oil may be advantageously used instead of water, with ordinary care no waste need take place, the wear of the plunger valves as well as the interior of the presses is much reduced by this plan. The Hydraulic Power Company, London, undertake to supply water under sufficient pressure from their mains to work hydraulic presses, in the same way they are supplying water for working hydraulic lifts; the pressure per square inch is increased by using differential rams and accumulators.

Pumps Used for Hay Pressing.—They are not usually made smaller than 1½-inch and 2 inches diameter, and in some instances where speed is of importance 2-inch pumps only are used; they are driven by a very powerful engine, special automatic arrangements being made in the engines, pumps, and mains, to adjust the speed to the requirements of the work.

Horizontal High-pressure Hydraulic Pumping Engines.

Engines for pumping water under heavy pressures for the purpose of working hydraulic cranes, hoists, and lifts, and also for hydraulic presses, are of a special character. The author proposes to notice two types of this class of pumping engine, horizontal and vertical; the former will be first treated. The introduction of water under high pressure in street mains, as now carried out in London and also at Hull by the "Hydraulic Power Company," has offered great facilities for the extension of hydraulic lifting machinery in places where it could not otherwise be adopted.

The pumping engines used at harbours, docks, railways, &c., are usually of the horizontal kind, and made in the form first introduced by Sir W. G. Armstrong and Co. The engines are coupled, there are two bed plates, the steam cylinders are fixed at one end of each plate, the hydraulic pressure pumps are placed immediately in front of the cylinders; the piston-rods work direct on to the pump rams or plungers, the pumps are double-acting, and form guides for the piston-rods; the connecting rods are made with long fork ends of sufficient width to clear the exterior of the pump barrels; at the cylinder end the rods are attached to a wrought-iron or steel crosshead; the piston-rods are keyed at one side and the pump plungers at the other; the reverse ends of the rods are attached direct to the crank pins of the discs or cranks. The valve boxes of the pump are usually placed at the side of the foundation stone of each engine, in a position convenient to permit of examination and for repairs. The valve boxes of the pumps are very strong, the valves are kept on their seats by alternate discs of indiarubber and steel, and are so adjusted that the compression of the indiarubber gives sufficient opening to allow the water to pass. Safety valves are put on the delivery to give relief to the pipes in case of any stoppage in the mains. The crank shaft is common to the two engines; it has one fly-wheel keyed on in the centre. No governor is used in these engines, the admission of steam is controlled by a sensitive throttle valve worked by means of gear from the accumulator, into which the water is pumped; when it is at the highest point the throttle valve is gradually closed, and as the accumulator falls it opens again.

The engines are thus adjusted to the requirements of the work, they are not quite stopped, and being coupled engines and the cranks set at right angles, they can start at any point of the stroke. The diameters of the steam cylinders and the pumps are adjusted to the work to be done. The working pressure of the pump is usually 700 lbs. per square inch; this pressure has been found in practice the most economical and gives the best results. The stroke of these engines is rather short in proportion to that used for ordinary pumping engines. The fly-wheels are made of moderate diameter, but heavy in the rim. The water is pumped into an "accumulator," which is a loaded ram working in a cylinder, and made in the form of a hydraulic press; the top of the ram carries a cage or casing containing iron or other weights, the size of the ram both as to diameter and stroke is regulated by the work to be done, and the load on the ram by the pressure it is desired to work at; the main pressure supply pipes lead direct from the bottom of the "accumulator."

Although this design has been somewhat modified by other makers, the type now described has seldom been surpassed for perfection of working and freedom from stoppages and breakdowns. A modification of the above plan is, where the pumps are placed at the back end of the steam cylinders; the only advantage gained is that the valve boxes can be got at more readily, while it is disadvantageous from the extra room or floor space it takes up.

Any one wishing more details in connection with the application of hydraulic power to cranes and lifts, or as to the accumulator and arrangement of allied parts of such machinery, is referred to the author's book upon 'Hydraulic Lifting and Pressing Machinery,' E. and F. N. Spon, London.

VERTICAL HIGH-PRESSURE HYDRAULIC PUMPING ENGINES (Drawing No. 34).—A very good type of these engines has been introduced by Mr. E. B. Ellington, M. Inst. C.E., and made by the Hydraulic Engineering Company at Chester. In these engines there are three inverted cylinders working three pumps direct; the two outer cylinders are low-pressure and the centre one high-pressure; the three cylinders work on one crank shaft. The arrangement of the pumps and connecting rods is similar to that in the horizontal engines before described. The high-pressure cylinders are worked expansively, the three cylinders are carried on side frames forming a surface condenser, and on wrought-iron columns, which are bolted to one bed plate. The connecting rods span the pump barrels and work on to crank pins on a three-throw crank working in bearings at the bed plate. The cranks are set at angles of 120°, there is thus no dead point in the stroke, and all parts of the engine are in perfect balance. It is a very neat and good arrangement, the engines work admirably and also very economically. The valve motion and method of working them is peculiar to the design, and is arranged as follows:—

The high-pressure main slide valve is placed on the centre line of the high-pressure cylinder, its face being parallel with the centre line of the crank shaft, and it is driven through a rocking-shaft by an eccentric. On the back of the main valve are two expansion plates on independent spindles, also driven through a rocking-shaft by an eccentric; links from the rocking-shaft levers have their other ends attached to well guided sleeves carrying triggers. The valve spindles would, were it not for the trigger gear, be free to slide in the sleeves, and each spindle moves forward for a certain period during the stroke, the length of this period being determined by the position of double cams, one actuated by the governor, and one by the accumulator. By contact with either cam the trigger is released, freeing the valve spindle which, being of comparatively large diameter, is smartly driven back by the pressure of steam in the valve chest, giving a sharp cut off. During the remainder of the stroke, the sleeve slides freely over the spindle until the trigger again slips into gear. A safety rod is provided to ensure the engaging of the trigger, in case of the spindle not travelling far enough under steam pressure, and dash pots are fitted to control the motion of the valve spindle.

This type of valve gear was originally introduced by the late Mr. Correy, manager to Messrs. Powell and Son, of Rouen, and has been successfully applied to a large number of engines.

The valves of the low-pressure cylinders are of the ordinary type, placed between the high- and low-pressure cylinders, and driven direct by eccentrics.

Pumping Engines used for the Supply of Hydraulic Pressure in the Hydraulic Power Company's mains in London; they are of the following dimensions:—

The two low-pressure cylinders are 25 inches diameter by 2 feet stroke; the centre or high-pressure cylinders 19 inches diameter by 2 feet stroke; the three pumps are each 5 inches diameter by 2 feet stroke; the pressure of steam used is 80 lbs. per square inch, cut off at about $\frac{3}{8}$ths of the stroke; the speed of the pump is 60 strokes per minute. The working pressure at the accumulator is 750 lbs. per square inch; the quantity of water pumped at this pressure is 17,400 gallons per hour, and the consumption of steam equals 20 lbs. per indicated horse-power. The consumption of small coal at 9*s.* per ton is 2 lbs. per indicated horse-power per hour. The useful effect of the pumps is equal to 84 per cent.

It will be seen that these engines are most economical; they work without vibration and noise, are easily controlled, and the speed is adjusted to the varied requirements of the work, it will be readily understood that in the case of public supply the work is very variable, and that special arrangements have to be made to meet this. Three years' experience of their working has proved the perfection of the design, and the arrangements of the whole machinery. The water is pumped into "accumulators" as before described, the arrangement of which does not materially differ.

STEAM FIRE ENGINES, MADE BY MESSRS. MERRYWEATHER AND SONS, LONDON.—These engines are made in various sizes to suit the requirements of different classes of work, those made by this firm for the "Metropolitan Fire Brigade" are constructed as follows:—

The boiler is vertical, and has an internal fire box, and central up-take tube of the usual kind, the boiler is made of Low Moor iron, the tubes are solid drawn steel, the top plate is solid flanged and is connected to the shell by rivets, and to the up-take tube by an angle iron riveted on it, and by bolts and nuts to the top plate; the fire-box is fitted with a large number of small tubes, some fixed horizontally and inclined, and others vertical, being curved at the lower part and riveted to the side plates of the fire-box. The lower part of the boiler is made conical in shape, the base being the largest diameter to permit large fire grate surface; it is claimed as an advantage, that the cold water descending passes up *inclined* or *ascending* tubes both in the horizontal and vertical ones. The lower part of the boiler is connected to the upper part by angle iron flanges, and held together by bolts and nuts; by this means ready access is obtained to the interior. Steam can be raised in 6 minutes to 100 lbs. per square inch, the usual average time is 9 to 10 minutes.

Boilers are also made by this firm upon the "Field" patent system, in which a number of small tubes with close bottoms having internal tubes open at each end, are suspended from the tôp plate of the fire-box, from the top of this plate a central up-take pipe is provided. The lower part of the boiler is made conical, the same as in the other boilers; manholes are provided in the top plate for removing tubes or examining the interior of the boiler. Very rapid circulation is obtained by these tubes, and steam is quickly generated. It is stated that a boiler can be re-tubed in three hours, and in case a tube is burned out, the boiler can be cooled down, the damaged tube withdrawn and the new one fixed in and started again with 100 lbs. of steam in about 14 minutes. Any ordinary workman can put in a tube; these boilers will evaporate from 10 lbs. to 10½ lbs. of water per pound of good coal.

In this case, as in the other, the machinery is placed at the front of the boiler, thus affording ready access to the fire doors. The coal is carried on the foot board in bunkers which contain about two hours' supply. The steam cylinders and the pumps are *not* attached to the boiler; they are direct-acting and fixed horizontally on wrought-iron framing; the cylinders and pumps are two in number. The pumps are gun-metal, double-acting, the valve seats are clear of any obstruction, and so are able to pass pieces of straw or shavings or similar obstructions; the pumps are fitted with copper air vessels, a constant supply of air is kept up within these vessels by means of an automatic arrangement. The wrought-iron frame of the engine is carried on springs and large wheels, the front wheels being made with a swivel carriage of the usual type. The hose box is carried next the driver's seat at the front of the engine; the dead weight of the boiler and machinery is equally distributed on the hind wheels. The cylinders and pumps are connected by a distance piece, and so take all the strain off the framing. The crank shaft, piston rods, valve, and connecting rods are of steel.

These engines are capable of throwing 350 gallons of water per minute under a head of 160 feet, through a jet 1⅛-inch diameter; the weight of the engine is about 28 cwt. There are various other forms of these engines; the following particulars will give an idea of their power and performance:—

The "*Conqueror*," double cylinder engine. The quantity of water thrown is 2000 gallons per minute, 300 feet high, through a jet 2¾ inches diameter; the weight is about 66 cwt.

The "*Cachapodl*" is built on the same plan as the last named; it is capable of throwing 1150 gallons of water to a height of 210 feet, through a 2-inch jet; the weight being 53 cwt.; these engines are not constructed to carry hose or firemen.

The "*Fire Queen*"; this is adapted for ordinary towns, as well as public establishments; it is built upon the same plan as the "Conqueror;" it is capable of pumping 900 gallons of water per minute to a height of 200 feet through a jet 1⅞-inch diameter; the weight of the engine being 50 cwt.

The "*Volunteer*" No. 1, is capable of pumping 260 gallons of water per minute to a heigh of 160 feet through a 1-inch diameter jet; the weight of the engine being 20 cwt.

There are a great number of other types of fire engines made by this firm; the above have been selected to give an idea of the performance of average sizes, as space will not permit a more detailed notice of them.

Steam Floating Fire Engines.

One of these will be taken as an example. The boat is iron, 45 feet long and 9 feet beam; the draft is 2 feet forward and 2 feet 6 inches backward; total depth, 4 feet 9 inches.

The vertical engines to drive the screws are supplied by the same boiler as for the fire engines. The speed of the boat is 10 statute miles per hour, the twin screws being 28 inches diameter. The fire engines are the "Admiralty" pattern; the two cylinders are each 8⅞ inches diameter and 24 inches stroke; the two pumps are each 6½ inches diameter, and the same stroke as the cylinders. The engine is capable of discharging 1150 gallons of water per minute, through a 1⅞-inch diameter jet, a height of 210 feet. The pumps and valves are gun-metal, the valves being faced with indiarubber. The boiler is Field's patent, and is capable of raising steam from cold water to 100 lbs. per square inch in 10 minutes from the time of lighting the fire.

These engines are made in six different sizes, three having two cylinders and two pumps and three one cylinder and one pump. There are many other forms of these engines made to suit special purposes; some are also adapted to act as "steam tugs," and also as sea-going "fire floats"; the engines and pumps in this case are made to discharge from 1000 to 4000 gallons of water per minute, the latter to a height of 260 feet through a 3½-inch jet, the nominal horse-power in this case being 200. The vessel is 86 feet long and 15 feet beam.

These large vessels are usually fitted with a pair of inverted cylinder engines. In some cases the engines are on the compound system. The twin screws permit the boat passing in and out of vessels or amongst craft in a crowded river or port.

The land engines are also sometimes placed in an ordinary barge, the wheels being fixed by scotches.

The combined fire floats and tugs are made 40 feet long and 10 feet beam; the draft of water is about 4 feet. The steam cylinders of the propelling engines are each 7½ inches diameter and 6½ inches stroke. The fire pumps can either be worked from the main engines, or by separate engines of the type before described; the hose-reels are placed on the deck fore and aft.

The author would wish it to be understood that in giving a description of land fire engines and steam floats made by the two leading firms (those by Messrs. Shand, Mason and Co. being described in the first part, pp. 26–29) he does not advocate any system, but gives particulars of the construction and performance of each, without considering relatively the merits of either from a manufacturer's point of view. These remarks are made to prevent any misunderstanding, as in these machines great competition exists, and it must be borne in mind in this book only a scientific description is aimed at quite apart from trade purposes. From the particulars and data given of working *results* the reader will be able to form his own judgment as to the machines most suitable for his purpose.

CHAPTER VI.

SUNDRY PUMPING MACHINERY.

Horizontal Direct-acting Blowing Engine for the Wingerworth Iron Company, Chesterfield (Drawing No. 35).—This engine was designed and manufactured by Messrs. Thornewill and Warham, Burton-on-Trent. The steam cylinder is 31 inches diameter by 5 feet stroke; it is fitted with variable expansion gear with regulating wheel and grade scale; the valve spindles are wrought iron, with adjustable joint ends fitted with gun-metal bushes; the rods pass through guides also lined with gun-metal, they are enlarged at this point to allow for wear. The steam jacket is cast on the cylinder, a cover is provided for examination and setting the slides; the main slide valve is D-shape, and the expansion valve is the grid type; the spindles of both valves pass through stuffing-boxes and glands at each end of the jacket. The steam pipe is 7½ inches diameter, and the exhaust 9 inches diameter. The cylinder has feet cast on it at each end, and is secured to the bed plate by four bolts; at the front end the feet are fitted between joggles cast upon the bed plate; this is for the purpose of taking the thrust off the bolts; the exterior of the cylinder is coated with composition and lagged with wood staves. The piston is of box section, fitted with junk ring and cast-iron packing rings, and secured to the rod by a steel collar. The rod is steel, 4¾ inches diameter; it is keyed to a wrought-iron cross head. The guide blocks are cast iron, 12 inches long; the guide bars are cast separate from the bed plate, and can thus be lined up as they wear. The connecting rod is wrought iron, 10 feet long by 4¾ inches diameter at ends; the end attached to the cross head pin is fitted with a strap, and that at the crank end is in the solid marine form; it is lined with gun-metal at each end. The crank is wrought iron; also the shaft, which is 8½ inches diameter in the bearings and 10 inches in the centre part. The fly-wheel is 14 feet 9 inches diameter and 8 inches wide, and weighs about 8½ tons; the rim is put together in three sections, and the arms and boss cast separately. The bed plate is 48 feet long and 12 inches deep; it is of the box section, and cast in two pieces and strongly joggled and bolted together. The blowing cylinder is 72 inches diameter by 5 feet stroke; it is placed behind the steam cylinder, the rods being coupled together by means of the slide block. The guide bars on this side are single, and are cast separate from the bed plate. The cylinder is connected to it by long flanges fitted between joggles cast upon the plate, and secured by eight bolts, the rod passes through the back end of the blowing cylinder, and is guided in the same manner as at the front. The valves are of leather, and beat upon planed faces bolted to the covers, the outlet valve casings are connected by a wrought-iron pipe. The blowing piston is packed with cup leathers and is lubricated with black lead.

The engine is capable of supplying 7000 cubic feet of air per minute at a pressure of 4¾ lbs. per square inch when running at 27 revolutions per minute and indicating 200 horse-power.

The pressure of steam used is 50 lbs. per square inch.

This engine has been working for years, and is doing very regular duty. It is a very inexpensive class to manufacture, and the wear is very small. The author has described one of a type made by this firm, they have also made a large number of engines for this purpose of various sizes.

Air Pumps for Pneumatic Dispatch.

The conveyance of telegrams between the central and branch offices in large towns is now generally performed by means of pneumatic tubes, through which carriers containing the written messages are propelled, in one direction by compressed air, in the other by the rarefaction of the air in the tubes, for which purposes engines working both air compressing and vacuum pumps are provided.

Messrs. Easton & Anderson of London, have erected several sets of such machinery; the first set was for the General Post Office in London, where they erected three compound condensing beam engines in 1872, and added a fourth engine in 1882; these engines work the whole of the pnuematic dispatch system of the Telegraph Department in London.

The machinery is placed in a yard in the middle of the building, in a light structure of timber and glass, wholly unconnected with the main building, so as not to transmit any vibration to it. Each engine has two cast iron bed-plates, each about 25 feet long; the lower one carrying two air pumps; the upper one is supported off the lower one by four cast iron frames, and forms the bed-plate of an ordinary compound condensing beam engine, the cylinders are 17 inches diameter by 49½ inches stroke and 25½ inches diameter by 66 inches stroke. The pumps are double-acting, 35 inches diameter by 36 inches stroke, and they are so arranged that any pump may be worked either for pressure or vacuum; any engine may work its pumps, so that both are on pressure or vacuum or that one is on pressure and one on vacuum.

The normal air pressure is 10 lbs. *above* the atmosphere, and the vacuum 8 lbs. *below* the atmosphere. These engines have kept up the day and night service without a single mishap causing interruption since they were started.

The same firm have also recently (in 1885) erected three 30 horse-power beam engines, each indicating 90 horse-power, for the same service at the Liverpool Post Office, under the supervision of Mr. J. W. Willmot of H.M. Postal Telegraph Department. Two of these engines are capable of doing all the work that is required, and the third one is kept in reserve; each engine has a single cylinder, steam jacketed and lagged, 18 inches diameter by 2 feet 7 inches stroke, and two double-acting service pumps (for pressure or vacuum). These are placed on one bed-plate, which carries the A frames in the middle, supporting the cast iron beam, and the entablature which is carried round the beam. The connecting rod works the crankshaft in the usual way, but both cylinder and crankshaft are nearer the centre than the pumps which are worked from the extreme ends of the beam beyond the cylinder on one side and the crankshaft on the other. The air pump is bolted to the bed-plate, and together with the condenser is placed underneath it; it is worked from the beam through the parellel motion for the cylinder and pumps, in the usual way; thus it will be seen that each engine is completely self contained. The main slide valve is worked by an eccentric of the usual type, but the expansion slide is worked from the beam.

Another example of similar machinery erected by the same firm, but on a smaller scale, is that of two single-cylinder non-condensing beam engines, at the Prudential Assurance Offices in Holborn, London, in the year 1878; they are very similar in general arrangement to those last described, except that they have no condenser. The steam cylinders are 16 inches diameter by 2 feet stroke, and the air service pumps are 16 inches diameter by 3 feet stroke; these small engines run at a speed of 45 revolutions per minute, the apparatus has given every satisfaction, and saves much labour in the office. Such plant could be usefully employed at hotels, large warehouses and factories where messages have to be constantly delivered, such service would be efficiently performed, and be both rapid and economical in working. The author hopes to see the system extended as it is applicable in many cases.

Airy and Anderson's Spiral Pumps.

Messrs. Easton & Anderson have applied these pumps for elevating water from settling ponds on to filter beds at the Waelhem pumping station of the Antwerp Waterworks, described on page 73 in first part.

They have also applied them for irrigation purposes in Egypt. The machinery erected at one of the stations consists of two inverted cylinder compound condensing engines with cylinders 26 inches and 50 inches diameter by 30 inches stroke, each engine working four spiral pumps by a steel shaft driven through gearing, one set of four pumps being on either side of the engine house. The pumps are 12 feet diameter by 39 feet long and the lift is 10 feet. Each pump delivers 30,000 gallons per minute i. e. 1,500,000 cubic metres per 24 hours.

The engines run at 75 revolutions, and the pumps at 6 revolutions per minute. The consumption of fuel was under 3 lbs. of *very inferior coal* per horse-power water lifted per hour.

Steam is supplied at 75 lbs. pressure per square inch by five marine multitubular boilers 10 feet 3 inches diameter by 11 feet 3 inches long, each with its separate iron chimney. These boilers were provided instead of those of the ordinary land type, in order to save expensive brick setting and chimney.

Water Towers.

Messrs. Easton & Anderson have adopted an arrangement of a tower supporting a cylindrical wrought iron tank for town and domestic water supplies with much success.

The tank erected by this firm for the Lymington Waterworks, Hants, may be taken as a very good example; it is constructed of wrought iron plates, riveted together, it is cylindrical in shape, and has a dished bottom, so as to dispense with the necessity for girders to support it; the entire weight being carried by the sides of the tank resting directly on the walls of the tower, thus distributing the weight uniformly all round on the walls, whilst the entire space in the tower, underneath the tank, is available for store rooms, workshops, &c. A cylindrical manhole pipe rises from the bottom of the tank to above the water level, with a ladder passing up it to give access to the inside of the tank as well as to the outside of the domed sheet-iron cover over it, which is reached through a manhole or trap door in the centre. The tank is 30 feet diameter, and the depth of water at the centre is 19 feet 6 inches, equal to a capacity of 75,000 gallons; the central manhole tube is 2 feet 9 inches diameter; the total height to the top of the tank is about 50 feet.

Sewage Pumps.

Buenos Ayres Sewage Works.—These pumping engines are by Messrs. Easton and Anderson. There are four compound condensing beam engines; they were constructed in 1883, and considered to embody all those points which experience has shown to be desirable. They are arranged in two coupled pairs, any single engine of which can work by itself; each pair of engines works four pumps, against a gross head of 50 feet; the sewage lifted being 13,100 gallons per minute at 15 revolutions, or 17,500 gallons at 20 revolutions.

The bed plates and A frames are of box section, and are very rigid; the frames have the bearings for the beam gudgeons formed in their upper ends, and are connected together by a distance piece of box section just below the beams. The spring beams are supported by the walls at their outer ends, and the only strains transmitted by them to the walls are half the vertical components of the angular pulls on the radius rods. The cylinders are steam-jacketed, felted, and lagged, and the high-pressure cylinders are fitted with Mr. W. E. Rich's improved type of expansion valves, so that the engines can be worked at very slow speeds. The high-pressure cylinders are 24 inches diameter by 46 inches stroke, and the low-pressure cylinders are 36 inches diameter and 72 inches stroke, giving a ratio of capacity of 3·5 to 1.

One of the pumps is worked by the prolongation of the high-pressure piston-rod through a stuffing-box in the cylinder bottom, the other pump is worked off the beam at the crank side of the main centre. In either case ample provision is made for opening the pump and removing the bucket; the outer end of the cast-iron beam is turned up so as to enable the crank shaft to be placed one foot further from the engine centre than the low-pressure cylinder without lengthening the stroke. By doing this the pump can be worked by a single rod without fouling the engine connecting rod. The air pump and feed pump are placed on a lower level than the bed plate, and are worked by a small beam from the crosshead of the high-pressure piston-rod.

The main pumps are of the single-acting lift type, 41 inches diameter and 46 inches stroke; the suction pipes are 36 inches and the delivery pipes to the air vessels 27 inches diameter; the delivery main from each pair of engines is 36 inches diameter.

Four boilers are provided in a house adjoining the engine house, each 7 feet diameter by 23 feet long, with two furnace flues 2 feet 9 inches diameter by 17 feet long, each containing six Galloway conical tubes and terminating in eighty-three tubes 3 inches diameter by 6 feet long.

This machinery was constructed under the supervision and to the specification of Mr. J. F. La Trobe Bateman, Past President of the Inst. C.E., Engineer to the Buenos Ayres Improvements Commission.

Water Wheels.

Scoop Wheels have been largely used in the fen and marsh districts, more especially for raising water, and may be noticed under the head of pumping machinery; but as they are not, strictly speaking, pumps, only a slight outline will be given of them. These machines are well adapted for raising large quantities of water to a small height; much power is, however, lost by them through leakage between the wheels and the masonry; only about 60 per cent. of useful effect is usually given by them. They are driven by windmills in some cases, or by steam engines, the latter are generally the most desirable, and are also more economical in working.

A scoop wheel with curved blades, 24 feet diameter by 4 feet wide, will deliver about 22,000 gallons per minute 4 feet high. A curved sluice or shuttle, which is capable of adjustment, is provided at the inlet to the wheel. The wheel is worked by a pinion from the engine shaft working into a spur rack fixed at the side of the wheel.

The wheels are now generally made of iron; formerly they were made almost entirely of wood. The iron wheels in use at the present day run on wrought-iron spindles or shafts; the bosses are made of cast iron bored out to receive the centre shaft, they have large plates, which have recesses in them into which the arms of the wheel are fitted. The shrouds are made separate, and have corresponding recesses cast in to receive the top ends of the arms, these are made of wrought iron; the buckets are made of wrought or cast iron; they are firmly bolted to flanges cast on the two side shrouds. The shape of the buckets has to be made suitable to the fall of water and the special circumstances of the case. The arms are stayed and braced diagonally.

Persian Wheels are used to raise water for irrigation purposes, they are made in light wrought iron, and in sizes up to 25 feet and 30 feet diameter; the wheels are driven by the stream by means of thin wrought-iron paddles. Small buckets of cast iron are fixed to the periphery of the wheel at one side, each of which dipping in the water carries it up to the top of the wheel and discharges it into an iron trough, at the bottom of the trough pipes are attached to take the water away as required. The buckets are made in the form of boxes closed on all sides, except a portion of the top, which is left open. A very small fall of water will work the wheels; they are very effective for the purpose for which they are used, they are not subjected to any great strain, and on this account last a long time, and being made very light, they work with very little friction. The speed of the wheels is very slow, depending upon the fall of water to work them. They have been used for a long period in China; they are usually made there of bamboo, and, like most of the Chinese work, they are constructed in a very ingenious manner, being both light and strong. Persian wheels are not much known in this country, they are, however, most useful for irrigation purposes where the land is moderately level.

Windmills.

These are used in this country, as well as in Holland, to work pumps; the power is, however, very variable, and cannot be relied on. As a rule water cannot be so economically pumped by windmills as by steam power, even when coal is very dear; in cases where small quantities of water have to be pumped from wells for the water supply of a private house or for irrigation purposes in fields or gardens, they may be used. A good sized tank or reservoir is, however, necessary, in order to have a sufficient store of water when there is not sufficient wind to drive the sails and keep the pumps at work. The pumps for raising water driven by windmills may be used as single, double, or treble barrels, and either fixed down a well or on the surface of the ground. The sails of the mill are attached to a horizontal shaft, slightly inclined, on the shaft a pinion-tooth wheel is keyed, this works a bevel wheel keyed on a vertical shaft, and by means of another pair of bevel wheels it is geared to the crank-shaft of the pumps. The sail-shaft is supported upon a frame of timber or wrought ironwork; self-acting gear is fitted at the top to turn the sails as the wind shifts. For small pumps a very light wheel will do; in this case instead of four blades or arms there are six or eight; they are made very light; they are very useful in a garden or farm, they require no attention, and being simple in construction are not liable to get out of order. This class of apparatus is noticed partly because it was one of the original kinds of motors, and also to point out that in some cases they may still be used with advantage. Windmills, as before named, are also used to drive scoop wheels for the drainage of fens and marshy districts.

Chain Pumps.

These pumps are made both with and without a back barrel, and either with square or round barrels; the barrels, when made square in shape, may either be of wood or iron, the former answering the purpose for temporary work, and more especially when used in foreign countries.

Murray's Patent Pumps were for many years favourites of this class, the chain in this case was fixed at the back of the bucket with another chain or sling fastened to the front side; in the event of any obstruction, by slightly reversing the chain it allows the bucket to be tilted, and the obstruction to be washed out by the upward velocity of the stream of water. The advantage of the back barrel is that men can work under the pump in the dry; the barrels are of cast iron, about 5 feet long, and are bolted together by means of flanges. The back barrel is made of wrought-iron plates, and about $\frac{1}{5}$th larger than the working or front barrel: this permits the buckets to pass down without friction.

In the cylindrical barrel pumps the buckets are attached at the centre to the endless chain; the back barrel is sometimes dispensed with; this kind of pump is suitable for deeper lifts than Murray's pumps named above. When the lift is deep, the buckets only fit at intervals in the barrel; these intermediate lengths of the barrel are made rather smaller than the other part, and are bell-mouthed at the top and bottom, to allow the buckets to pass easily in and out of them. The object of this arrangement is to save friction; one of the working or smaller parts of the barrel *must always be placed at the bottom of the pump.* The buckets, which are usually covered with indiarubber or leather, fit easy in the large part of the barrel, but closely at the working parts.

Chain Pumps, with a 6-inch diameter barrel, will pump about 300 gallons per hour, and those of 12 inches diameter about 1200, this latter is the largest size used.

The chains and buckets have, of course, to be proportioned in strength to the working depths; the links of the chain should be made a dead length from centre to centre of the pin holes. This is done by drilling them in a standard gauge or template; the holes should be case-hardened, the pins should be of steel and turned. Upon the accurate construction of the chain much of the success of the pump depends, and for this reason the Author recommends that none but the best work of the kind should be used, as a cheap and badly constructed pump will often cost a large sum in repairs, and also much loss of time and inconvenience. In river or embankment work, the break down of a pump at a critical time may be attended with serious consequences.

Messrs. Warner and Sons of London, have introduced an improvement by substituting long double links for the usual chains. No stretch takes place in them as with the chain, there is less friction and noise in working; it is also claimed that the power to work the pumps is reduced, and the quantity of water delivered is larger than in the ordinary types.

CHAPTER VII.

TABLES OF WATER PUMPING.

It has been suggested to the Author that information upon the actual performance of pumping engines would be more convenient if shown in the form of tables; as part of the information now given is scattered in different portions of the book, the matter has been collected and included in the tables, together with other data of working results kindly furnished by friends. As the circumstances of nearly all cases differ, the merits of each must be judged separately. In Table No. 4, in which the cost of pumping is given, the district where the work is done, and the description as well as the cost of coal must be duly considered in forming any conclusion as to the relative merits of the machinery.

Tables Nos. 8, 9, 10, and 11 are given to show cost of pumping water in Philadelphia and Chicago, they are very valuable, and of much interest.

In instances where the engines are constantly working day and night, and where their power is ample for the work to be done, also where the quantity of water dealt with is large, the cost of pumping is much reduced. Much difficulty has been experienced in getting actual results of working, especially as to the coal consumed and cost of repairs of the pumping plant, as in many instances the cost of coal, &c., for pumping purposes, is not kept separate.

The Author trusts that he has put the information in a form acceptable to his readers. He will feel obliged for any suggestions for additions and improvements for the next edition; he takes this opportunity to thank the gentlemen who have kindly helped him with information to form the tables. Great care has been used in the preparation of the Tables in order to avoid errors, especially in overstating the work accomplished by the various engines mentioned.

TABLE No. 1.

WORK PERFORMED BY BEAM COMPOUND PUMPING ENGINES, HIGH LIFTS.

Description of Engine.	I.H.P.	Diameter and Stroke of Cylinder.	Revolutions per Minute.	Size of Pumps.	Height lifted.	Quantity Pumped.	Coal consumed per I.H.P.	Maker's Name, and where at Work.
		in.		in.	ft.	gallons.		
Beam compound, one engine.	300	28 × 64 stroke and 46 × 96	16	2, 33½ × 30 1, 24 × 42 1, 24 × 48	129 92 166	..	3·02	Easton and Anderson, Brighton Waterworks.
Compound, one engine.	140	27 × 36 and 38 × 60	22	20 × 36	160	2376 per minute.	..	Easton and Anderson, Portsmouth Waterworks.
Compound, two engines	163	22½ and 45 × 66	22	2, 22½ and 16 × 33	226	2083 per minute.	..	Easton and Anderson, Lambeth Waterworks.
Compound, two pairs = four engines	100	18½ × 44 and 30 × 66	22	22½ and 16 × 33	280	1042 per minute.	..	Easton and Anderson, Antwerp Waterworks.
Compound, one engine.	75	15 × 37½ and 25 × 54	30	3, 14 × 24 3, 11¾ × 24 fixed in well, 13 revs. of crank.	200	516 per minute from one set, and 360 per minute second set.	..	Easton and Anderson, Ramsgate Waterworks.
Compound, one engine, as last.	45	12½ × 24 20 × 36	40	One set of 3, 11¾ × 24 at 12 revs. of crank.	275	338 per minute.	..	Easton and Anderson, Sevenoaks Waterworks.
Compound, three pumps, worked direct from beam.	..	18½ × 44 and 30 × 66	22	3 pumps 1, 18 × 33 1, 12 × 36 1, 14 × 16¾	182 291 526	650 325 200 } per min.	..	Easton and Anderson, Sutton Waterworks.
Compound, two pumps, direct from beam.	..	17 × 49½ and 25½ × 66	25	2 pumps 16¼ × 24	175	900 per minute.	..	Easton and Anderson, Winchester.
Compound, two engines.	306	28 × 66⅝ and 46 × 96	19	23⅝ × 83	219	Lbs. raised 1 ft. high by 112 lbs. coals. 111,350,000	2·0	Simpson and Co., Chelsea Waterworks.

TABLE No. 1—*continued.*

Description of Engine.	I.H.P.	Diameter and Stroke of Cylinder.	Revolutions per Minute.	Size of Pumps.	Height lifted.	Quantity Pumped.	Coal consumed per I.H.P.	Maker's Name, and where at Work.
		in.		in.	ft.	gallons.		
Compound, two sets.	238 (total)	21 and 36 × 60	240 feet of piston per min.	27 × 48 4 to each engine	34¾	490,000 each.	2·15	Simpson, and Co., Lambeth, Ditton works.
Compound, two pairs.	117 (each)	25½ and 38 × 60	19	4 pumps 17½ × 55	196	224,161 per hour.	2·3	Simpson and Co., at Clifton, Waterworks.
Two colliery horizontal compound engines and two pumps.	..	30 × 48 and 54 × 48	20	2 pumps 10 × 48 double-acting.	510	800 and 1000 at 32 revs.	..	Thornewill and Warham, at Denby Colliery.

TABLE No. 2.

PUMPING WATER FOR MEDIUM LIFTS 20 FEET TO 50 FEET HIGH.

Description of Engine.	I.H.P.	Cylinder Diameter and Stroke.	Height lifted.	Quantity pumped per hour.	Coal used per actual horse-power.	Cost, &c., of Coal per ton.	Cost per million gallons.	Efficiency or Duty.	Maker's Name, &c.
		in.	ft. in.	galls.	lbs.		s. d.		
Two vertical condensing..	40 each	30 × 48	20 0	416,666	4·2	13s.	4 4	..	Simpson and Co.
Compound beam	238 7	H-P. 21, L-P. 36 × 60	34 9	492,350	2·6	Welsh coal	..	80 millions	Simpson and Co.
Davey's patent differential engine..	86	.. ..	20 0	300,000					

TABLE No. 3.

COMPARATIVE WORKING OF COMPOUND CONDENSING AND NON-CONDENSING PUMPING ENGINES.

Description of Engine.	Cylinder Diameter and Stroke.	Pressure of Steam.	Revolutions per Minute.	Size of Pumps.	Quantity pumped per Hour.	Coal used per Hour.	Head of Water.	Duty per cwt. of Coal.	Coal used per horse-power per hour.	Coal used per 1000 gallons.	I.H.P.	Coal used per I.H.P. per hour.	Coal used per 1000 gallons.	Efficiency of Machinery.	Cost of Coal to pump 1 million gallons.	Cost of Oil and Coal per 1 million gallons.	Cost of Coal per 1000 gallons raised 100 feet.	Remarks.
	in.	lbs. per sq. in.		in.	galls.	lbs.	ft.		lbs.	lbs.		lbs.	d.		s. d.	s. d.	d.	
Compound	H-P. 12½ L-P. 22 × 18, stroke.	72	48	6×18	20,310	80	254	72,222,360	3·08	3·9	30·99	2·58	·153 at 7s. 3d. per ton.	·84	12 9	14 5	·068*	The actual head of water pumped was 52 feet extra, which was caused by friction in the mains.
Condensing	22 × 18	44	48	Do.	10,236	65·39	209	36,674,126	6·05	6·38	14·6	4·47	·2478	·74	20 8	24 0		
High-Pressure.	12½ × 18	70	48·8	Do.	10,286	75·25	195	29,853,321	7·43	7·31	13·3	5·66	·2841	·76	23 8	26 2		

* This will now be reduced to ·065*d.*

This table of results was given to the author by Mr. J. Mansergh, M.I.C.E., of work done at the Stockton and Middlesbrough Waterworks, Eston Pumping Station. The engines were made by Messrs. Worth, Mackenzie and Co., of Stockton-on-Tees.

The average of seven years' cost of pumping 1000 gallons of water 100 feet high at the main pumping station, Broken Scar, Darlington, was ·1943*d.* The average (of seven years) is made up thus:—

	d.
Coal	·1353
Wages	·0431
Stores	·0159
Total	·1943 = 16*s.* 2*d.* per million gallons raised 100 feet.

TABLE No. 4.

PUMPING WATER FOR HIGH LIFTS.

Description of Engine.	Kind and Cost of Coal in the Stores.	Coal used per million gallons.	Coal used per actual H-P. work.	Duty lbs. raised 1 foot high by 112 lbs. Coal.	Total Cost of pumping 1 million gallons, exclusive of Interest on Capital.	Head of Water.	Cylinder Diameter and Stroke.	Steam Pressure.	Remarks.
		cwt.	lbs.			ft.	in.	lbs.	
Cornish Beam ..	Medium Welsh, 11*s*. 6*d*. per ton.	20	3¼	75,000,000	14*s*. 9*d*.	180	..	..	At Kew Bridge, G.J.W. Co., per A. Fraser, M.I.C.E. The height given is an average, as the head varies.
Do. "Bull"	Welsh, 21*s*. per ton	20¼	2·46	70,000,000	30*s*.	140	..	40	Large London Waterworks.
Compound Beam	North Country small, 11*s*. 8*d*. per ton.	33	2·3	70,000,000	35*s*.	210	H-P. 28 L-P. 42 × 96	40	Large London Waterworks, four engines = 600 horse-power, constantly at work.
Davey's Patent	Lancashire small, 11*s*. 3*d*. per ton.	..	..	..	21*s*.	100	..	..	At a Colliery at St. Helens.
Compound Beam	"Ryhope" North Country Coal, 12*s*. per ton.	ton 1·19	2·72	81,000,000	14*s*. 2*d*.	195	H-P. 30 × 66 L-P. 46 × 96 Pump 18½ × 83	57	At Chelsea Waterworks, Surbiton. Mr. R. Hack, M.I.C.E. Coal in use is very common.
One pair Horizontal Compound.	16*s*. per ton.	cwt. 18¾	3·03	73,200,000	..	137	H-P. 21½ × 48 L-P. 35 × 48 Pumps 12½ × 48	60 cut off at $\frac{3}{10}$ths	West Middlesex Waterworks, Barrow Hill, by Simpson and Co.

TABLE No. 5.

WORK PERFORMED BY CENTRIFUGAL PUMPS.

Description and Maker.	Size of Fan or suction pipe.	Kind of Engine.	Revs. per min. engine.	I.H.P.	Speed of Fan, revs. per min.	Height lifted.	Quantity discharged.	Efficiency.	Coal per H-P.	Place.
Appold, Easton & Anderson, three sets	in. 96 diam. fan by 35 deep, three pumps.	in. Three vertical cylinders, 30 by 30 s.	52	260	92·5	9ft. 10 in.	230 tons per min. each pump.	..	..	Amsterdam Ship Canal.
Ditto, two sets	84 diam. by 27 deep.	30 by 30, two cylinders.	38·7	196	68·8	4 ft. 8 in. to 6 ft. 1 in.	356 to 395 tons per min. by each pump.	64 p. c.	..	Whitham.
Ditto, one pump	72 diam. by 48 deep.	Compound, 15 by 37½ and 25 diam. by 48 s.	32	113	92·7	10·114 ft.	88 tons per min.	53½ p. c.	..	Whittlesea Mere.
Ditto, ditto	40 diam. fan by 8¾ deep.	41 h-p. nominal, portable engine.	..	..	..	5 ft. to 13 ft.	6,500 galls at mean lift.	..	..	Redmoor.
Ditto, ditto	78 diam. by 20 deep.	Same as Nos. 1 & 2.	..	..	..	26 ft. 3½ in. maximum height.	19,000 tons in 2½ hours.	..	..	Portsmouth Dockyard.
Ditto, four sets	58 diam. fan by 10 deep.	One horizontal condensing engine, 27 diam. by 36.	..	..	..	39 ft. maximum at end of pumping.	Four pumps discharge 34,000 tons water in 1¾ hours.	..	..	Cronstadt Dockyard.
Ditto, ditto	66 diam. by 10 deep.	Two cylinder engines to each, 14 diam. by 15 s.	..	..	..	23 ft. maximum lift.	Four pumps discharge 26,400 tons in 2½ hours.	..	..	Graving Dock, Glasgow.
Gwynne, I. and H., eight pumps, engine to each	60 diam. fan and 54 suction pipe.	Compound, 27¾ and 46 by 27 s.	..	..	..	7 ft. 3 in. mean lift.	200 square miles of country drained, or 500,000 gallons of water per min. by 8 pumps.	..	2 lbs.	Ferrara Marsh, Italy.

TABLE No. 5—*continued.*

Description and Maker.	Size of Fan or suction pipe.	Kind of Engine.	Revs. per min. engine.	I.H.P.	Speed of Fan, revs. per min.	Height lifted.	Quantity discharged.	Efficiency.	Coal per H.P.	Place.
Gwynne, I. and H., two pumps	in. 36 suction	in. Horizontal engines.	..	..	..	10 ft. 6 in.	30,818 gallons per minute.	..	cwt. 73½ in 24 hours	Holland, Polder, Grootslag.
Ditto, four 36-inch pumps, one 15 in.	60-in. fans diam.	21½ diam. by 24 s., horizontal.	..	..	..	10 ft. 2¾ in.	Ten acres raised 5 ft. in 90 min.	..	34 cwt.	Mersey Dock, Liverpool.
Hick, Hargreaves and Co., two pumps and two engines	48-in. fan	16 diam. by 36 s., horizontal h-p.	100	..	250	25 ft.	5,793,867 gallons in 4 hours.	..	..	Morel Dock, Cardiff.
Simpson and Co., one large pump.	Fan 60 by 7¾, suction pipe 84, delivery pipe 60.	Two vertical engines, cylinders 22½ diam. by 16½ s.	..	187	192	33 feet maximum	3758 gallons per min. by one pump.	37 millions	5·87	Tilbury Docks.
R. Moreland and Sons	72-in. fan, suction pipe 38.	Vertical compound 26 and 44 diam. by 26 s.	130	..	130	35 ft. maximum	6250 tons of water per hour.	..	..	New Graving Dock, Malta.

TABLE No. 6.

AIRY'S PATENT SPIRAL PUMP.

Diameter of Fan.	Speed per min.	Height lifted.	Quantity per hour.	Efficiency per cent.	Coal used per I.H.P.
12 feet	6 revolutions	10·66 feet	1,876,000 galls.	85	3·15 lbs.

The above work done in Egypt.

TABLE No. 7.

WORK PERFORMED BY DIRECT-ACTING PUMPING ENGINES—HIGH LIFTS.

Description of Engine.	I.H.P.	Diameter and Stroke of Cylinder.	Revolutions per minute.	Size of Pumps.	Height lifted.	Quantity in gallons per hour.	Coal used per H-P.	Duty.	Maker's Name and where worked.
		in.		in.	ft.				
Horizontal Non-condensing.	140	24 by 48 s.	22	9 by 48, double-acting	240	40,000	..	..	Hick, Hargreaves and Co., at Woolwich Arsenal.
Cameron's Pump	..	26 diam. by 72 s.	10 double strokes, 40 lbs. steam.	6½ diam. by 72.	1000	9,000	8 lbs. I.H.P., unscreened at pit.	63 cwt. coal to lift one million gallons 100 feet high.	Colliery, North of England.
Thornewill and Warham, Patent Pump, direct-acting.	..	10 by 12 s.	60 strokes	5 by 12 s.	50	7,500			
Tonkins' "Cornish" Pump.	..	26 diam. by 48 s., 40 lbs. steam.	12 double strokes.	8½ diam. by 48 s.	450	13,000	Small coal from colliery, no account taken.	..	Colliery at Barnsley.
Ditto	..	40 diam. by 48 s.	..	10 diam. by 48 s.	1000	20,000	Ditto	..	North of England.
Ditto (vertical) engine.	..	14 diam. by 24 s., 55 lbs. steam.	..	8 diam. by 24 s.	300	28,000	Ditto	..	Colliery at Cheshire.

NOTE.—The probable coal consumption of the Tonkins' Pump will be about 7 to 8 lbs. per I.H.P. of unscreened coal.

TABLE No. 8.

WORK PERFORMED BY PUMPING ENGINES AT PHILADELPHIA, U.S., IN 1884 (ONE YEAR'S WORK).

Engines.	Time run in hours.	Gallons pumped. (U.S.)	Pressure in lbs. per sq. in.	Coal used per year.	Gallons raised 100 feet per lb. coal.
Simpson Compound	1,991¼	749,620,000	51		
Cramp Compound	6,762	4,911,288,450	78		
Worthington ..	2,566¼	1,231,965,840	63		
Totals	11,319	6,892,874,290	average 64	tons 9,610	537

TABLE No. 9.

RUNNING EXPENSES OF NINE PUMPING STATIONS AT PHILADELPHIA, U.S., 1884 (ONE YEAR'S WORK).

	$	c.
Salaries of employes	57,885	22
Coal used, 28,880 tons, at $3 39c.	97,995	05
Oil for engine, 2864 gallons..	1,706	32
Lighting station, gas	4,734	60
„ „ oil	206	59
„ „ electric light (all expenses) ..	885	95
Repairs to machinery and boilers	48,374	63
Stores	4,383	15
Total expenses	$216,171	51

Total gallons (U.S.) pumped	25,495,179,353
Lift in feet, including friction	152·2
Gallons pumped 100 feet high, including friction	39,001,865,294
Cost of raising water 100 feet per million gallons	$5 54c.

The above particulars were given to the author by Mr. J. G. Mair, M.I.C.E.

TABLE No. 10.

COST OF PUMPING WATER AT NORTH PUMPING WORKS AT CHICAGO IN 1885 (ONE YEAR'S WORK).

	$	c.
Salaries of engineers	7,300	00
Labour, firemen, &c.	17,350	97
Coal, 12,970½ tons at $5 58c. per ton	72,419	48
Cylinder oil and lard oil	705	24
Solidified oil	156	25
Tallow	9	36
Packing	38	87
Waste	138	09
Stores	92	38
Gas	962	40
Repairs, fire tools	63	93
„ engines	284	51
„ boilers	883	40
	$100,404	88

	$	c.
Cost of delivering water per million gallons (U.S.) 113 feet high	7	16$\frac{93}{100}$
Ditto ditto 1 foot high	0	06$\frac{34}{100}$
Gallons (U.S.) pumped in one year	14,004,733,925	

TABLE No. 11.

COST OF PUMPING WATER AT WEST PUMPING STATION, CHICAGO (ONE YEAR'S WORK), 1885.

	$	c.
Gallons (U.S.) pumped during year under 105 feet head	19,447,521,980	
Total cost	96,391	00
Cost of pumping 1 million gallons 105 feet high ..	4	95
Cost of delivering 1 million gallons 1 foot high	0	4$\frac{71}{100}$
Cost of repairs, engines and boiler, per million gallons	0	10$\frac{28}{100}$
Cost of coal per ton	3	35

NOTE.—Tables Nos. 10 and 11 were given the author by Mr. J. G. Mair, M.I.C.E.

INDEX.

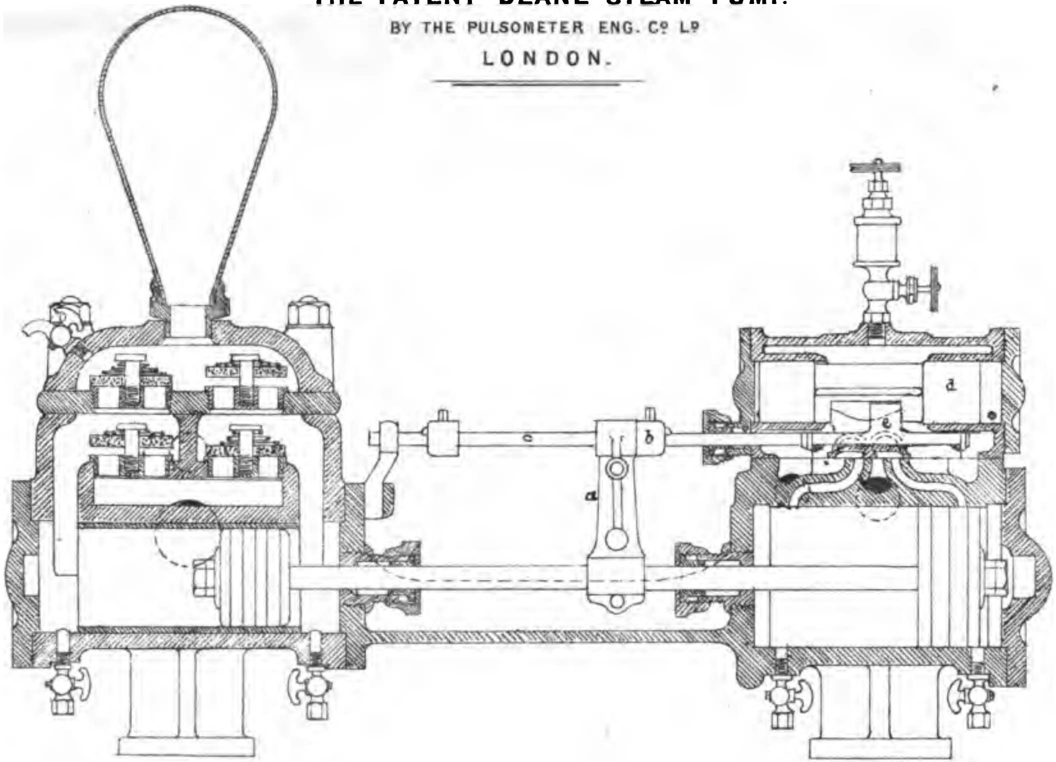
F

LONDON: PRINTED BY WILLIAM CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.

THE PATENT "DEANE" STEAM PUMP.

BY THE PULSOMETER ENG. Co. Ld.

LONDON.

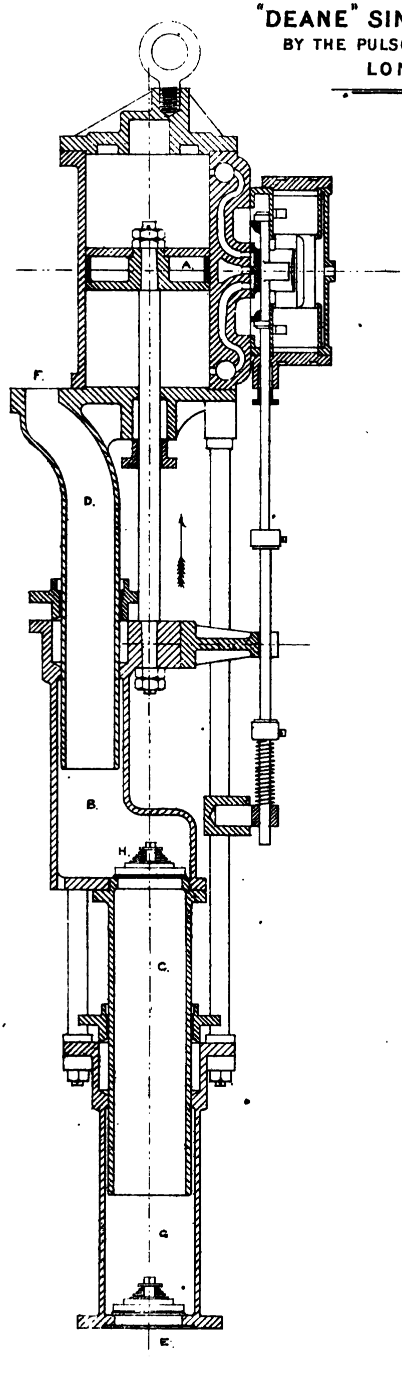


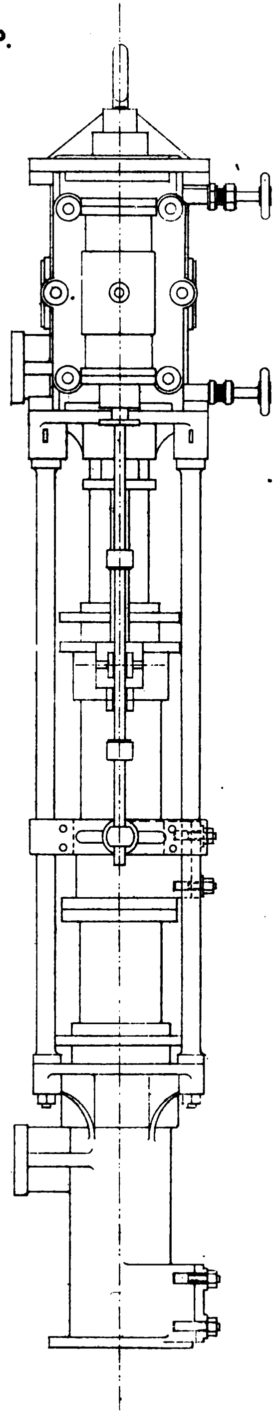
F. COLYER, M. INST. C.E.

"DEANE" SINKING PUMP.

BY THE PULSOMETER ENG. Co. Ld.

LONDON.





F. COLYER, M. INST. C. E.

1888.

BOOKS RELATING
TO
APPLIED SCIENCE,
PUBLISHED BY
E. & F. N. SPON,
LONDON: 125, STRAND.

NEW YORK: 12, CORTLANDT STREET.

A Pocket-Book for Chemists, Chemical Manufacturers, Metallurgists, Dyers, Distillers, Brewers, Sugar Refiners, Photographers, Students, etc., etc. By THOMAS BAYLEY, Assoc. R.C. Sc. Ireland, Analytical and Consulting Chemist and Assayer. Fourth edition, with additions, 437 pp., royal 32mo, roan, gilt edges, 5*s*.

SYNOPSIS OF CONTENTS:

Atomic Weights and Factors—Useful Data—Chemical Calculations—Rules for Indirect Analysis—Weights and Measures—Thermometers and Barometers—Chemical Physics—Boiling Points, etc.—Solubility of Substances—Methods of Obtaining Specific Gravity—Conversion of Hydrometers—Strength of Solutions by Specific Gravity—Analysis—Gas Analysis—Water Analysis—Qualitative Analysis and Reactions—Volumetric Analysis—Manipulation—Mineralogy—Assaying—Alcohol—Beer—Sugar—Miscellaneous Technological matter relating to Potash, Soda, Sulphuric Acid, Chlorine, Tar Products, Petroleum, Milk, Tallow, Photography, Prices, Wages, Appendix, etc., etc.

The Mechanician: A Treatise on the Construction and Manipulation of Tools, for the use and instruction of Young Engineers and Scientific Amateurs, comprising the Arts of Blacksmithing and Forging; the Construction and Manufacture of Hand Tools, and the various Methods of Using and Grinding them; the Construction of Machine Tools, and how to work them; Machine Fitting and Erection; description of Hand and Machine Processes; Turning and Screw Cutting; principles of Constructing and details of Making and Erecting Steam Engines, and the various details of setting out work, etc., etc. By CAMERON KNIGHT, Engineer. *Containing* 1147 *illustrations*, and 397 pages of letter-press, Fourth edition, 4to, cloth, 18*s*.

B

Just Published, in Demy 8vo, cloth, containing 975 pages and 250 Illustrations, price 7s. 6d.

SPONS' HOUSEHOLD MANUAL:

A Treasury of Domestic Receipts and Guide for Home Management.

PRINCIPAL CONTENTS.

Hints for selecting a good House, pointing out the essential requirements for a good house as to the Site, Soil, Trees, Aspect, Construction, and General Arrangement; with instructions for Reducing Echoes, Waterproofing Damp Walls, Curing Damp Cellars.

Sanitation.—What should constitute a good Sanitary Arrangement; Examples (with illustrations) of Well- and Ill-drained Houses; How to Test Drains; Ventilating Pipes, etc.

Water Supply.—Care of Cisterns; Sources of Supply; Pipes; Pumps; Purification and Filtration of Water.

Ventilation and Warming.—Methods of Ventilating without causing cold draughts, by various means; Principles of Warming; Health Questions; Combustion; Open Grates; Open Stoves; Fuel Economisers; Varieties of Grates; Close-Fire Stoves; Hot-air Furnaces; Gas Heating; Oil Stoves; Steam Heating; Chemical Heaters; Management of Flues; and Cure of Smoky Chimneys.

Lighting.—The best methods of Lighting; Candles, Oil Lamps, Gas, Incandescent Gas, Electric Light; How to test Gas Pipes; Management of Gas.

Furniture and Decoration.—Hints on the Selection of Furniture; on the most approved methods of Modern Decoration; on the best methods of arranging Bells and Calls; How to Construct an Electric Bell.

Thieves and Fire.—Precautions against Thieves and Fire; Methods of Detection; Domestic Fire Escapes; Fireproofing Clothes, etc.

The Larder.—Keeping Food fresh for a limited time; Storing Food without change, such as Fruits, Vegetables, Eggs, Honey, etc.

Curing Foods for lengthened Preservation, as Smoking, Salting, Canning, Potting, Pickling, Bottling Fruits, etc.; Jams, Jellies, Marmalade, etc.

The Dairy.—The Building and Fitting of Dairies in the most approved modern style; Butter-making; Cheesemaking and Curing.

The Cellar.—Building and Fitting; Cleaning Casks and Bottles; Corks and Corking; Aërated Drinks; Syrups for Drinks; Beers; Bitters; Cordials and Liqueurs; Wines; Miscellaneous Drinks.

The Pantry.—Bread-making; Ovens and Pyrometers; Yeast; German Yeast; Biscuits; Cakes; Fancy Breads; Buns.

The Kitchen.—On Fitting Kitchens; a description of the best Cooking Ranges, close and open; the Management and Care of Hot Plates, Baking Ovens, Dampers, Flues, and Chimneys; Cooking by Gas; Cooking by Oil; the Arts of Roasting, Grilling, Boiling, Stewing, Braising, Frying.

Receipts for Dishes—Soups, Fish, Meat, Game, Poultry, Vegetables, Salads, Puddings, Pastry, Confectionery, Ices, etc., etc.; Foreign Dishes.

The Housewife's Room.—Testing Air, Water, and Foods; Cleaning and Renovating; Destroying Vermin.

Housekeeping, Marketing.

The Dining-Room.—Dietetics; Laying and Waiting at Table; Carving; Dinners, Breakfasts, Luncheons, Teas, Suppers, etc.

The Drawing-Room.—Etiquette; Dancing; Amateur Theatricals; Tricks and Illusions; Games (indoor).

The Bedroom and Dressing-Room; Sleep; the Toilet; Dress; Buying Clothes; Outfits; Fancy Dress.

The Nursery.—The Room; Clothing; Washing; Exercise; Sleep; Feeding; Teething; Illness; Home Training.

The Sick-Room.—The Room; the Nurse; the Bed; Sick Room Accessories; Feeding Patients; Invalid Dishes and Drinks; Administering Physic; Domestic Remedies; Accidents and Emergencies; Bandaging; Burns; Carrying Injured Persons; Wounds; Drowning; Fits; Frost-bites; Poisons and Antidotes; Sunstroke; Common Complaints; Disinfection, etc.

The Bath-Room.—Bathing in General; Management of Hot-Water System.

The Laundry.—Small Domestic Washing Machines, and methods of getting up linen; Fitting up and Working a Steam Laundry.

The School-Room.—The Room and its Fittings; Teaching, etc.

The Playground.—Air and Exercise; Training; Outdoor Games and Sports.

The Workroom.—Darning, Patching, and Mending Garments.

The Library.—Care of Books.

The Garden.—Calendar of Operations for Lawn, Flower Garden, and Kitchen Garden.

The Farmyard.—Management of the Horse, Cow, Pig, Poultry, Bees, etc., etc.

Small Motors.—A description of the various small Engines useful for domestic purposes, from 1 man to 1 horse power, worked by various methods, such as Electric Engines, Gas Engines, Petroleum Engines, Steam Engines, Condensing Engines, Water Power, Wind Power, and the various methods of working and managing them.

Household Law.—The Law relating to Landlords and Tenants, Lodgers, Servants, Parochial Authorities, Juries, Insurance, Nuisance, etc.

On Designing Belt Gearing. By E. J. COWLING WELCH, Mem. Inst. Mech. Engineers, Author of 'Designing Valve Gearing.' Fcap. 8vo, sewed, 6*d.*

A Handbook of Formulæ, Tables, and Memoranda, for Architectural Surveyors and others engaged in Building. By J. T. HURST, C.E. Fourteenth edition, royal 32mo, roan, 5*s.*

"It is no disparagement to the many excellent publications we refer to, to say that in our opinion this little pocket-book of Hurst's is the very best of them all, without any exception. It would be useless to attempt a recapitulation of the contents, for it appears to contain almost *everything* that anyone connected with building could require, and, best of all, made up in a compact form for carrying in the pocket, measuring only 5 in. by 3 in., and about ¾ in. thick, in a limp cover. We congratulate the author on the success of his laborious and practically compiled little book, which has received unqualified and deserved praise from every professional person to whom we have shown it."—*The Dublin Builder.*

Tabulated Weights of Angle, Tee, Bulb, Round, Square, and Flat Iron and Steel, and other information for the use of Naval Architects and Shipbuilders. By C. H. JORDAN, M.I.N.A. Fourth edition, 32mo, cloth, 2*s.* 6*d.*

A Complete Set of Contract Documents for a Country Lodge, comprising Drawings, Specifications, Dimensions (for quantities), Abstracts, Bill of Quantities, Form of Tender and Contract, with Notes by J. LEANING, printed in facsimile of the original documents, on single sheets fcap., in paper case, 10*s.*

A Practical Treatise on Heat, as applied to the Useful Arts; for the Use of Engineers, Architects, &c. By THOMAS BOX. *With* 14 *plates.* Third edition, crown 8vo, cloth, 12*s.* 6*d.*

A Descriptive Treatise on Mathematical Drawing Instruments: their construction, uses, qualities, selection, preservation, and suggestions for improvements, with hints upon Drawing and Colouring. By W. F. STANLEY, M.R.I. Fifth edition, *with numerous illustrations,* crown 8vo, cloth, 5*s.*

Quantity Surveying. By J. LEANING. With 42 illustrations. Second edition, revised, crown 8vo, cloth, 9*s.*

CONTENTS:

A complete Explanation of the London Practice.
General Instructions.
Order of Taking Off.
Modes of Measurement of the various Trades.
Use and Waste.
Ventilation and Warming.
Credits, with various Examples of Treatment.
Abbreviations.
Squaring the Dimensions.
Abstracting, with Examples in illustration of each Trade.
Billing.
Examples of Preambles to each Trade.
Form for a Bill of Quantities.
Do. Bill of Credits.
Do. Bill for Alternative Estimate.
Restorations and Repairs, and Form of Bill.
Variations before Acceptance of Tender.
Errors in a Builder's Estimate.
Schedule of Prices.
Form of Schedule of Prices.
Analysis of Schedule of Prices.
Adjustment of Accounts.
Form of a Bill of Variations.
Remarks on Specifications.
Prices and Valuation of Work, with Examples and Remarks upon each Trade.
The Law as it affects Quantity Surveyors, with Law Reports.
Taking Off after the Old Method.
Northern Practice.
The General Statement of the Methods recommended by the Manchester Society of Architects for taking Quantities.
Examples of Collections.
Examples of "Taking Off" in each Trade.
Remarks on the Past and Present Methods of Estimating.

Spons' Architects' and Builders' Price Book, with useful Memoranda. Edited by W. YOUNG, Architect. Crown 8vo, cloth, red edges, 3*s.* 6*d.* *Published annually.* Sixteenth edition. *Now ready.*

Long-Span Railway Bridges, comprising Investigations of the Comparative Theoretical and Practical Advantages of the various adopted or proposed Type Systems of Construction, with numerous Formulæ and Tables giving the weight of Iron or Steel required in Bridges from 300 feet to the limiting Spans; to which are added similar Investigations and Tables relating to Short-span Railway Bridges. Second and revised edition. By B. BAKER, Assoc. Inst. C.E. *Plates,* crown 8vo, cloth, 5*s.*

Elementary Theory and Calculation of Iron Bridges and Roofs. By AUGUST RITTER, Ph.D., Professor at the Polytechnic School at Aix-la-Chapelle. Translated from the third German edition, by H. R. SANKEY, Capt. R.E. With 500 *illustrations,* 8vo, cloth, 15*s.*

The Elementary Principles of Carpentry. By THOMAS TREDGOLD. Revised from the original edition, and partly re-written, by JOHN THOMAS HURST. Contained in 517 pages of letterpress, and *illustrated with* 48 *plates and* 150 *wood engravings.* Sixth edition, reprinted from the third, crown 8vo, cloth, 12*s.* 6*d.*

Section I. On the Equality and Distribution of Forces—Section II. Resistance of Timber—Section III. Construction of Floors—Section IV. Construction of Roofs—Section V. Construction of Domes and Cupolas—Section VI. Construction of Partitions—Section VII. Scaffolds, Staging, and Gantries—Section VIII. Construction of Centres for Bridges—Section IX. Coffer-dams, Shoring, and Strutting—Section X. Wooden Bridges and Viaducts—Section XI. Joints, Straps, and other Fastenings—Section XII. Timber.

The Builder's Clerk: a Guide to the Management of a Builder's Business. By THOMAS BALES. Fcap. 8vo, cloth, 1*s.* 6*d.*

Our Factories, Workshops, and Warehouses: their Sanitary and Fire-Resisting Arrangements. By B. H. THWAITE, Assoc. Mem. Inst. C.E. *With* 183 *wood engravings*, crown 8vo, cloth, 9*s.*

Gold: Its Occurrence and Extraction, embracing the Geographical and Geological Distribution and the Mineralogical Characters of Gold-bearing rocks; the peculiar features and modes of working Shallow Placers, Rivers, and Deep Leads; Hydraulicing; the Reduction and Separation of Auriferous Quartz; the treatment of complex Auriferous ores containing other metals; a Bibliography of the subject and a Glossary of Technical and Foreign Terms. By ALFRED G. LOCK, F.R.G.S. *With numerous illustrations and maps*, 1250 pp., super-royal 8vo, cloth, 2*l.* 12*s.* 6*d.*

Iron Roofs: Examples of Design, Description. *Illustrated with* 64 *Working Drawings of Executed Roofs.* By ARTHUR T. WALMISLEY, Assoc. Mem. Inst. C.E. Second edition, revised, imp. 4to, half-morocco, 3*l.* 3*s.*

A History of Electric Telegraphy, to the Year 1837. Chiefly compiled from Original Sources, and hitherto Unpublished Documents, by J. J. FAHIE, Mem. Soc. of Tel. Engineers, and of the International Society of Electricians, Paris. Crown 8vo, cloth, 9*s.*

Spons' Information for Colonial Engineers. Edited by J. T. HURST. Demy 8vo, sewed.

No. 1, Ceylon. By ABRAHAM DEANE, C.E. 2*s.* 6*d.*

CONTENTS:

Introductory Remarks—Natural Productions—Architecture and Engineering—Topography, Trade, and Natural History—Principal Stations—Weights and Measures, etc., etc.

No. 2. Southern Africa, including the Cape Colony, Natal, and the Dutch Republics. By HENRY HALL, F.R.G.S., F.R.C.I. With Map. 3*s.* 6*d.*

CONTENTS:

General Description of South Africa—Physical Geography with reference to Engineering Operations—Notes on Labour and Material in Cape Colony—Geological Notes on Rock Formation in South Africa—Engineering Instruments for Use in South Africa—Principal Public Works in Cape Colony: Railways, Mountain Roads and Passes, Harbour Works, Bridges, Gas Works, Irrigation and Water Supply, Lighthouses, Drainage and Sanitary Engineering, Public Buildings, Mines—Table of Woods in South Africa—Animals used for Draught Purposes—Statistical Notes—Table of Distances—Rates of Carriage, etc.

No. 3. India. By F. C. DANVERS, Assoc. Inst. C.E. With Map. 4*s.* 6*d.*

CONTENTS:

Physical Geography of India—Building Materials—Roads—Railways—Bridges—Irrigation—River Works—Harbours—Lighthouse Buildings—Native Labour—The Principal Trees of India—Money—Weights and Measures—Glossary of Indian Terms, etc.

A Practical Treatise on Coal Mining. By GEORGE G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Member of the Society of Engineers. *With* 82 *lithographic plates.* 2 vols., royal 4to, cloth, 3*l.* 12*s.*

A Practical Treatise on Casting and Founding, including descriptions of the modern machinery employed in the art. By N. E. SPRETSON, Engineer. Third edition, with 82 *plates* drawn to scale, 412 pp., demy 8vo, cloth, 18*s.*

The Depreciation of Factories and their Valuation. By EWING MATHESON, M. Inst. C.E. 8vo, cloth, 6*s.*

A Handbook of Electrical Testing. By H. R. KEMPE, M.S.T.E. Fourth edition, revised and enlarged, crown 8vo, cloth, 16*s.*

Gas Works: their Arrangement, Construction, Plant, and Machinery. By F. COLYER, M. Inst. C.E. *With* 31 *folding plates,* 8vo, cloth, 24*s.*

The Clerk of Works: a Vade-Mecum for all engaged in the Superintendence of Building Operations. By G. G. HOSKINS, F.R.I.B.A. Third edition, fcap. 8vo, cloth, 1*s.* 6*d.*

American Foundry Practice: Treating of Loam, Dry Sand, and Green Sand Moulding, and containing a Practical Treatise upon the Management of Cupolas, and the Melting of Iron. By T. D. WEST, Practical Iron Moulder and Foundry Foreman. Second edition, *with numerous illustrations,* crown 8vo, cloth, 10*s.* 6*d.*

The Maintenance of Macadamised Roads. By T. CODRINGTON, M.I.C.E, F.G.S., General Superintendent of County Roads for South Wales. 8vo, cloth, 6*s.*

Hydraulic Steam and Hand Power Lifting and Pressing Machinery. By FREDERICK COLYER, M. Inst. C.E., M. Inst. M.E. *With* 73 *plates,* 8vo, cloth, 18*s.*

Pumps and Pumping Machinery. By F. COLYER, M.I.C.E., M.I.M.E. *With* 23 *folding plates,* 8vo, cloth, 12*s.* 6*d.*

Pumps and Pumping Machinery. By F. COLYER. Second Part. *With* 11 *large plates,* 8vo, cloth, 12*s.* 6*d.*

A Treatise on the Origin, Progress, Prevention, and Cure of Dry Rot in Timber; with Remarks on the Means of Preserving Wood from Destruction by Sea-Worms, Beetles, Ants, etc. By THOMAS ALLEN BRITTON, late Surveyor to the Metropolitan Board of Works, etc., etc. *With* 10 *plates,* crown 8vo, cloth, 7*s.* 6*d.*

The Municipal and Sanitary Engineer's Handbook.

By H. PERCY BOULNOIS, Mem. Inst. C.E., Borough Engineer, Portsmouth. *With numerous illustrations*, demy 8vo, cloth, 12*s*. 6*d*.

CONTENTS:

The Appointment and Duties of the Town Surveyor—Traffic—Macadamised Roadways—Steam Rolling—Road Metal and Breaking—Pitched Pavements—Asphalte—Wood Pavements—Footpaths—Kerbs and Gutters—Street Naming and Numbering—Street Lighting—Sewerage—Ventilation of Sewers—Disposal of Sewage—House Drainage—Disinfection—Gas and Water Companies, etc., Breaking up Streets—Improvement of Private Streets—Borrowing Powers—Artizans' and Labourers' Dwellings—Public Conveniences—Scavenging, including Street Cleansing—Watering and the Removing of Snow—Planting Street Trees—Deposit of Plans—Dangerous Buildings—Hoardings—Obstructions—Improving Street Lines—Cellar Openings—Public Pleasure Grounds—Cemeteries—Mortuaries—Cattle and Ordinary Markets—Public Slaughter-houses, etc.—Giving numerous Forms of Notices, Specifications, and General Information upon these and other subjects of great importance to Municipal Engineers and others engaged in Sanitary Work.

Metrical Tables. By G. L. MOLESWORTH, M.I.C.E.

32mo, cloth, 1*s*. 6*d*.

CONTENTS.

General—Linear Measures—Square Measures—Cubic Measures—Measures of Capacity—Weights—Combinations—Thermometers.

Elements of Construction for Electro-Magnets. By

Count TH. DU MONCEL, Mem. de l'Institut de France. Translated from the French by C. J. WHARTON. Crown 8vo, cloth, 4*s*. 6*d*.

Practical Electrical Units Popularly Explained, with

numerous illustrations and Remarks. By JAMES SWINBURNE, late of J. W. Swan and Co., Paris, late of Brush-Swan Electric Light Company, U.S.A. 18mo, cloth, 1*s*. 6*d*.

A Treatise on the Use of Belting for the Transmission of Power.

By J. H. COOPER. Second edition, *illustrated*, 8vo, cloth, 15*s*.

A Pocket-Book of Useful Formulæ and Memoranda

for Civil and Mechanical Engineers. By GUILFORD L. MOLESWORTH, Mem. Inst. C.E., Consulting Engineer to the Government of India for State Railways. *With numerous illustrations*, 744 pp. Twenty-second edition, revised and enlarged, 32mo, roan, 6*s*.

SYNOPSIS OF CONTENTS:

Surveying, Levelling, etc.—Strength and Weight of Materials—Earthwork, Brickwork, Masonry, Arches, etc.—Struts, Columns, Beams, and Trusses—Flooring, Roofing, and Roof Trusses—Girders, Bridges, etc.—Railways and Roads—Hydraulic Formulæ—Canals, Sewers, Waterworks, Docks—Irrigation and Breakwaters—Gas, Ventilation, and Warming—Heat, Light, Colour, and Sound—Gravity: Centres, Forces, and Powers—Millwork, Teeth of Wheels, Shafting, etc.—Workshop Recipes—Sundry Machinery—Animal Power—Steam and the Steam Engine—Water-power, Water-wheels, Turbines, etc.—Wind and Windmills—Steam Navigation, Ship Building, Tonnage, etc.—Gunnery, Projectiles, etc.—Weights, Measures, and Money—Trigonometry, Conic Sections, and Curves—Telegraphy—Mensuration—Tables of Areas and Circumference, and Arcs of Circles—Logarithms, Square and Cube Roots, Powers—Reciprocals, etc.—Useful Numbers—Differential and Integral Calculus—Algebraic Signs—Telegraphic Construction and Formulæ.

Hints on Architectural Draughtsmanship. By G. W. TUXFORD HALLATT. Fcap. 8vo, cloth, 1*s.* 6*d.*

Spons' Tables and Memoranda for Engineers; selected and arranged by J. T. HURST, C.E., Author of 'Architectural Surveyors' Handbook,' 'Hurst's Tredgold's Carpentry,' etc. Ninth edition, 64mo, roan, gilt edges, 1*s.*; or in cloth case, 1*s.* 6*d.*

This work is printed in a pearl type, and is so small, measuring only 2½ in. by 1¾ in. by ¼ in. thick, that it may be easily carried in the waistcoat pocket.

"It is certainly an extremely rare thing for a reviewer to be called upon to notice a volume measuring but 2½ in. by 1¾ in., yet these dimensions faithfully represent the size of the handy little book before us. The volume—which contains 118 printed pages, besides a few blank pages for memoranda—is, in fact, a true pocket-book, adapted for being carried in the waistcoat pocket, and containing a far greater amount and variety of information than most people would imagine could be compressed into so small a space. . . . . The little volume has been compiled with considerable care and judgment, and we can cordially recommend it to our readers as a useful little pocket companion."—*Engineering.*

A Practical Treatise on Natural and Artificial Concrete, its Varieties and Constructive Adaptations. By HENRY REID, Author of the 'Science and Art of the Manufacture of Portland Cement.' New Edition, *with* 59 *woodcuts and* 5 *plates*, 8vo, cloth, 15*s.*

Notes on Concrete and Works in Concrete; especially written to assist those engaged upon Public Works. By JOHN NEWMAN, Assoc. Mem. Inst. C.E., crown 8vo, cloth, 4*s.* 6*d.*

Electricity as a Motive Power. By Count TH. DU MONCEL, Membre de l'Institut de France, and FRANK GERALDY, Ingénieur des Ponts et Chaussées. Translated and Edited, with Additions, by C. J. WHARTON, Assoc. Soc. Tel. Eng. and Elec. *With* 113 *engravings and diagrams*, crown 8vo, cloth, 7*s.* 6*d.*

Treatise on Valve-Gears, with special consideration of the Link-Motions of Locomotive Engines. By Dr. GUSTAV ZEUNER, Professor of Applied Mechanics at the Confederated Polytechnikum of Zurich. Translated from the Fourth German Edition, by Professor J. F. KLEIN, Lehigh University, Bethlehem, Pa. *Illustrated*, 8vo, cloth, 12*s.* 6*d.*

The French-Polisher's Manual. By a French-Polisher; containing Timber Staining, Washing, Matching, Improving, Painting, Imitations, Directions for Staining, Sizing, Embodying, Smoothing, Spirit Varnishing, French-Polishing, Directions for Re-polishing. Third edition, royal 32mo, sewed, 6*d.*

Hops, their Cultivation, Commerce, and Uses in various Countries. By P. L. SIMMONDS. Crown 8vo, cloth, 4*s.* 6*d.*

The Principles of Graphic Statics. By GEORGE SYDENHAM CLARKE, Capt. Royal Engineers. *With* 112 *illustrations.* 4to, cloth, 12*s.* 6*d.*

Dynamo-Electric Machinery: A Manual for Students of Electro-technics. By SILVANUS P. THOMPSON, B.A., D.Sc., Professor of Experimental Physics in University College, Bristol, etc., etc. Third edition, *illustrated*, 8vo, cloth, 16*s.*

Practical Geometry, Perspective, and Engineering Drawing; a Course of Descriptive Geometry adapted to the Requirements of the Engineering Draughtsman, including the determination of cast shadows and Isometric Projection, each chapter being followed by numerous examples; to which are added rules for Shading, Shade-lining, etc., together with practical instructions as to the Lining, Colouring, Printing, and general treatment of Engineering Drawings, with a chapter on drawing Instruments. By GEORGE S. CLARKE, Capt. R.E. Second edition, *with 21 plates.* 2 vols., cloth, 10*s.* 6*d.*

The Elements of Graphic Statics. By Professor KARL VON OTT, translated from the German by G. S. CLARKE, Capt. R.E., Instructor in Mechanical Drawing, Royal Indian Engineering College. *With* 93 *illustrations*, crown 8vo, cloth, 5*s.*

A Practical Treatise on the Manufacture and Distribution of Coal Gas. By WILLIAM RICHARDS. Demy 4to, with *numerous wood engravings and* 29 *plates*, cloth, 28*s.*

SYNOPSIS OF CONTENTS:

Introduction—History of Gas Lighting—Chemistry of Gas Manufacture, by Lewis Thompson, Esq., M.R.C.S.—Coal, with Analyses, by J. Paterson, Lewis Thompson, and G. R. Hislop, Esqrs.—Retorts, Iron and Clay—Retort Setting—Hydraulic Main—Condensers—Exhausters—Washers and Scrubbers—Purifiers—Purification—History of Gas Holder—Tanks, Brick and Stone, Composite, Concrete, Cast-iron, Compound Annular Wrought-iron—Specifications—Gas Holders—Station Meter—Governor—Distribution—Mains—Gas Mathematics, or Formulæ for the Distribution of Gas, by Lewis Thompson, Esq.—Services—Consumers' Meters—Regulators—Burners—Fittings—Photometer—Carburization of Gas—Air Gas and Water Gas—Composition of Coal Gas, by Lewis Thompson, Esq.—Analyses of Gas—Influence of Atmospheric Pressure and Temperature on Gas—Residual Products—Appendix—Description of Retort Settings, Buildings, etc., etc.

The New Formula for Mean Velocity of Discharge of Rivers and Canals. By W. R. KUTTER. Translated from articles in the 'Cultur-Ingénieur,' by LOWIS D'A. JACKSON, Assoc. Inst. C.E. 8vo, cloth, 12*s.* 6*d.*

The Practical Millwright and Engineer's Ready Reckoner; or Tables for finding the diameter and power of cog-wheels, diameter, weight, and power of shafts, diameter and strength of bolts, etc. By THOMAS DIXON. Fourth edition, 12mo, cloth, 3*s.*

Tin: Describing the Chief Methods of Mining, Dressing and Smelting it abroad; with Notes upon Arsenic, Bismuth and Wolfram. By ARTHUR G. CHARLETON, Mem. American Inst. of Mining Engineers. *With plates*, 8vo, cloth, 12*s.* 6*d.*

Perspective, Explained and Illustrated. By G. S. CLARKE, Capt. R.E. *With illustrations,* 8vo, cloth, 3*s.* 6*d.*

Practical Hydraulics; a Series of Rules and Tables for the use of Engineers, etc., etc. By THOMAS BOX. Fifth edition, *numerous plates,* post 8vo, cloth, 5*s.*

The Essential Elements of Practical Mechanics; based on the Principle of Work, designed for Engineering Students. By OLIVER BYRNE, formerly Professor of Mathematics, College for Civil Engineers. Third edition, *with* 148 *wood engravings,* post 8vo, cloth, 7*s.* 6*d.*

CONTENTS:

Chap. 1. How Work is Measured by a Unit, both with and without reference to a Unit of Time—Chap. 2. The Work of Living Agents, the Influence of Friction, and introduces one of the most beautiful Laws of Motion—Chap. 3. The principles expounded in the first and second chapters are applied to the Motion of Bodies—Chap. 4. The Transmission of Work by simple Machines—Chap. 5. Useful Propositions and Rules.

Breweries and Maltings: their Arrangement, Construction, Machinery, and Plant. By G. SCAMELL, F.R.I.B.A. Second edition, revised, enlarged, and partly rewritten. By F. COLYER, M.I.C.E., M.I.M.E. *With* 20 *plates,* 8vo, cloth, 18*s.*

A Practical Treatise on the Construction of Horizontal and Vertical Waterwheels, specially designed for the use of operative mechanics. By WILLIAM CULLEN, Millwright and Engineer. *With* 11 *plates.* Second edition, revised and enlarged, small 4to, cloth, 12*s.* 6*d.*

A Practical Treatise on Mill-gearing, Wheels, Shafts, Riggers, etc.; for the use of Engineers. By THOMAS BOX. Third edition, *with* 11 *plates.* Crown 8vo, cloth, 7*s.* 6*d.*

Mining Machinery: a Descriptive Treatise on the Machinery, Tools, and other Appliances used in Mining. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E., Mem. of the Society of Engineers. Royal 4to, uniform with the Author's Treatise on Coal Mining, containing 182 *plates,* accurately drawn to scale, with descriptive text, in 2 vols., cloth, 3*l.* 12*s.*

CONTENTS:

Machinery for Prospecting, Excavating, Hauling, and Hoisting—Ventilation—Pumping—Treatment of Mineral Products, including Gold and Silver, Copper, Tin, and Lead, Iron Coal, Sulphur, China Clay, Brick Earth, etc.

Tables for Setting out Curves for Railways, Canals, Roads, etc., varying from a radius of five chains to three miles. By A. KENNEDY and R. W. HACKWOOD. *Illustrated,* 32mo, cloth, 2*s.* 6*d.*

The Science and Art of the Manufacture of Portland Cement, with observations on some of its constructive applications. *With 66 illustrations.* By HENRY REID, C.E., Author of 'A Practical Treatise on Concrete,' etc., etc. 8vo, cloth, 18*s.*

The Draughtsman's Handbook of Plan and Map Drawing; including instructions for the preparation of Engineering, Architectural, and Mechanical Drawings. *With numerous illustrations in the text, and* 33 *plates* (15 *printed in colours*). By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. 4to, cloth, 9*s.*

CONTENTS:

The Drawing Office and its Furnishings—Geometrical Problems—Lines, Dots, and their Combinations—Colours, Shading, Lettering, Bordering, and North Points—Scales—Plotting—Civil Engineers' and Surveyors' Plans—Map Drawing—Mechanical and Architectural Drawing—Copying and Reducing Trigonometrical Formulæ, etc., etc.

The Boiler-maker's and Iron Ship-builder's Companion, comprising a series of original and carefully calculated tables, of the utmost utility to persons interested in the iron trades. By JAMES FODEN, author of 'Mechanical Tables,' etc. Second edition revised, *with illustrations,* crown 8vo, cloth, 5*s.*

Rock Blasting: a Practical Treatise on the means employed in Blasting Rocks for Industrial Purposes. By G. G. ANDRÉ, F.G.S., Assoc. Inst. C.E. *With* 56 *illustrations and* 12 *plates*, 8vo, cloth, 10*s.* 6*d.*

Painting and Painters' Manual: a Book of Facts for Painters and those who Use or Deal in Paint Materials. By C. L. CONDIT and J. SCHELLER. *Illustrated*, 8vo, cloth, 10*s.* 6*d.*

A Treatise on Ropemaking as practised in public and private Rope-yards, with a Description of the Manufacture, Rules, Tables of Weights, etc., adapted to the Trade, Shipping, Mining, Railways, Builders, etc. By R. CHAPMAN, formerly foreman to Messrs. Huddart and Co., Limehouse, and late Master Ropemaker to H.M. Dockyard, Deptford. Second edition, 12mo, cloth, 3*s.*

Laxton's Builders' and Contractors' Tables; for the use of Engineers, Architects, Surveyors, Builders, Land Agents, and others. Bricklayer, containing 22 tables, with nearly 30,000 calculations. 4to, cloth, 5*s.*

Laxton's Builders' and Contractors' Tables. Excavator, Earth, Land, Water, and Gas, containing 53 tables, with nearly 24,000 calculations. 4to, cloth, 5*s.*

Sanitary Engineering: a Guide to the Construction of Works of Sewerage and House Drainage, with Tables for facilitating the calculations of the Engineer. By BALDWIN LATHAM, C.E., M. Inst. C.E., F.G.S., F.M.S., Past-President of the Society of Engineers. Second edition, *with numerous plates and woodcuts*, 8vo, cloth, 1*l.* 10*s.*

Screw Cutting Tables for Engineers and Machinists, giving the values of the different trains of Wheels required to produce Screws of any pitch, calculated by Lord Lindsay, M.P., F.R.S., F.R.A.S., etc. Cloth, oblong, 2*s.*

Screw Cutting Tables, for the use of Mechanical Engineers, showing the proper arrangement of Wheels for cutting the Threads of Screws of any required pitch, with a Table for making the Universal Gas-pipe Threads and Taps. By W. A. MARTIN, Engineer. Second edition, oblong, cloth, 1*s.*, or sewed, 6*d.*

A Treatise on a Practical Method of Designing Slide-Valve Gears by Simple Geometrical Construction, based upon the principles enunciated in Euclid's Elements, and comprising the various forms of Plain Slide-Valve and Expansion Gearing; together with Stephenson's, Gooch's, and Allan's Link-Motions, as applied either to reversing or to variable expansion combinations. By EDWARD J. COWLING WELCH, Memb. Inst. Mechanical Engineers. Crown 8vo, cloth, 6*s.*

Cleaning and Scouring: a Manual for Dyers, Laundresses, and for Domestic Use. By S. CHRISTOPHER. 18mo, sewed, 6*d.*

A Glossary of Terms used in Coal Mining. By WILLIAM STUKELEY GRESLEY, Assoc. Mem. Inst. C.E., F.G.S., Member of the North of England Institute of Mining Engineers. *Illustrated with numerous woodcuts and diagrams*, crown 8vo, cloth, 5*s.*

A Pocket-Book for Boiler Makers and Steam Users, comprising a variety of useful information for Employer and Workman, Government Inspectors, Board of Trade Surveyors, Engineers in charge of Works and Slips, Foremen of Manufactories, and the general Steam-using Public. By MAURICE JOHN SEXTON. Second edition, royal 32mo, roan, gilt edges, 5*s.*

Electrolysis: a Practical Treatise on Nickeling, Coppering, Gilding, Silvering, the Refining of Metals, and the treatment of Ores by means of Electricity. By HIPPOLYTE FONTAINE, translated from the French by J. A. BERLY, C.E., Assoc. S.T.E. *With engravings.* 8vo, cloth, 9*s.*

Barlow's Tables of Squares, Cubes, Square Roots, Cube Roots, Reciprocals of all Integer Numbers up to 10,000. Post 8vo, cloth, 6*s.*

A Practical Treatise on the Steam Engine, containing Plans and Arrangements of Details for Fixed Steam Engines, with Essays on the Principles involved in Design and Construction. By ARTHUR RIGG, Engineer, Member of the Society of Engineers and of the Royal Institution of Great Britain. Demy 4to, *copiously illustrated with woodcuts and* 96 *plates*, in one Volume, half-bound morocco, 2*l.* 2*s.*; or cheaper edition, cloth, 25*s.*

This work is not, in any sense, an elementary treatise, or history of the steam engine, but is intended to describe examples of Fixed Steam Engines without entering into the wide domain of locomotive or marine practice. To this end illustrations will be given of the most recent arrangements of Horizontal, Vertical, Beam, Pumping, Winding, Portable, Semi-portable, Corliss, Allen, Compound, and other similar Engines, by the most eminent Firms in Great Britain and America. The laws relating to the action and precautions to be observed in the construction of the various details, such as Cylinders, Pistons, Piston-rods, Connecting-rods, Cross-heads, Motion-blocks, Eccentrics, Simple, Expansion, Balanced, and Equilibrium Slide-valves, and Valve-gearing will be minutely dealt with. In this connection will be found articles upon the Velocity of Reciprocating Parts and the Mode of Applying the Indicator, Heat and Expansion of Steam Governors, and the like. It is the writer's desire to draw illustrations from every possible source, and give only those rules that present practice deems correct.

A Practical Treatise on the Science of Land and Engineering Surveying, Levelling, Estimating Quantities, etc., with a general description of the several Instruments required for Surveying, Levelling, Plotting, etc. By H. S. MERRETT. Fourth edition, revised by G. W. USILL, Assoc. Mem. Inst. C.E. 41 *plates, with illustrations and tables,* royal 8vo, cloth, 12*s.* 6*d.*

PRINCIPAL CONTENTS:

Part 1. Introduction and the Principles of Geometry. Part 2. Land Surveying; comprising General Observations—The Chain—Offsets Surveying by the Chain only—Surveying Hilly Ground—To Survey an Estate or Parish by the Chain only—Surveying with the Theodolite—Mining and Town Surveying—Railroad Surveying—Mapping—Division and Laying out of Land—Observations on Enclosures—Plane Trigonometry. Part 3. Levelling—Simple and Compound Levelling—The Level Book—Parliamentary Plan and Section—Levelling with a Theodolite—Gradients—Wooden Curves—To Lay out a Railway Curve—Setting out Widths. Part 4. Calculating Quantities generally for Estimates—Cuttings and Embankments—Tunnels—Brickwork—Ironwork—Timber Measuring. Part 5. Description and Use of Instruments in Surveying and Plotting—The Improved Dumpy Level—Troughton's Level—The Prismatic Compass—Proportional Compass—Box Sextant—Vernier—Pantagraph—Merrett's Improved Quadrant—Improved Computation Scale—The Diagonal Scale—Straight Edge and Sector. Part 6. Logarithms of Numbers—Logarithmic Sines and Co-Sines, Tangents and Co-Tangents—Natural Sines and Co-Sines—Tables for Earthwork, for Setting out Curves, and for various Calculations, etc., etc., etc.

Health and Comfort in House Building, or Ventilation with Warm Air by Self-Acting Suction Power, with Review of the mode of Calculating the Draught in Hot-Air Flues, and with some actual Experiments. By J. DRYSDALE, M.D., and J. W. HAYWARD, M.D. Second edition, with Supplement, *with plates,* demy 8vo, cloth, 7*s.* 6*d.*

The Assayer's Manual: an Abridged Treatise on the Docimastic Examination of Ores and Furnace and other Artificial Products. By BRUNO KERL. Translated by W. T. BRANNT. *With* 65 *illustrations*, 8vo, cloth, 12*s*. 6*d*.

Electricity: its Theory, Sources, and Applications. By J. T. SPRAGUE, M.S.T.E. Second edition, revised and enlarged, *with numerous illustrations*, crown 8vo, cloth, 15*s*.

The Practice of Hand Turning in Wood, Ivory, Shell, etc., with Instructions for Turning such Work in Metal as may be required in the Practice of Turning in Wood, Ivory, etc.; also an Appendix on Ornamental Turning. (A book for beginners.) By FRANCIS CAMPIN. Third edition, *with wood engravings*, crown 8vo, cloth, 6*s*.

CONTENTS:

On Lathes—Turning Tools—Turning Wood—Drilling—Screw Cutting—Miscellaneous Apparatus and Processes—Turning Particular Forms—Staining—Polishing—Spinning Metals—Materials—Ornamental Turning, etc.

Treatise on Watchwork, Past and Present. By the Rev. H. L. NELTHROPP, M.A., F.S.A. *With* 32 *illustrations*, crown 8vo, cloth, 6*s*. 6*d*.

CONTENTS:

Definitions of Words and Terms used in Watchwork—Tools—Time—Historical Summary—On Calculations of the Numbers for Wheels and Pinions; their Proportional Sizes, Trains, etc.—Of Dial Wheels, or Motion Work—Length of Time of Going without Winding up—The Verge—The Horizontal—The Duplex—The Lever—The Chronometer—Repeating Watches—Keyless Watches—The Pendulum, or Spiral Spring—Compensation—Jewelling of Pivot Holes—Clerkenwell—Fallacies of the Trade—Incapacity of Workmen—How to Choose and Use a Watch, etc.

Algebra Self-Taught. By W. P. HIGGS, M.A., D.Sc., LL.D., Assoc. Inst. C.E., Author of 'A Handbook of the Differential Calculus,' etc. Second edition, crown 8vo, cloth, 2*s*. 6*d*.

CONTENTS:

Symbols and the Signs of Operation—The Equation and the Unknown Quantity—Positive and Negative Quantities—Multiplication—Involution—Exponents—Negative Exponents—Roots, and the Use of Exponents as Logarithms—Logarithms—Tables of Logarithms and Proportionate Parts—Transformation of System of Logarithms—Common Uses of Common Logarithms—Compound Multiplication and the Binomial Theorem—Division, Fractions, and Ratio—Continued Proportion—The Series and the Summation of the Series—Limit of Series—Square and Cube Roots—Equations—List of Formulæ, etc.

Spons' Dictionary of Engineering, Civil, Mechanical, Military, and Naval; with technical terms in French, German, Italian, and Spanish, 3100 pp., and *nearly* 8000 *engravings*, in super-royal 8vo, in 8 divisions, 5*l*. 8*s*. Complete in 3 vols., cloth, 5*l*. 5*s*. Bound in a superior manner, half-morocco, top edge gilt, 3 vols., 6*l*. 12*s*.

Notes in Mechanical Engineering. Compiled principally for the use of the Students attending the Classes on this subject at the City of London College. By HENRY ADAMS, Mem. Inst. M.E., Mem. Inst. C.E., Mem. Soc. of Engineers. Crown 8vo, cloth, 2s. 6d.

Canoe and Boat Building: a complete Manual for Amateurs, containing plain and comprehensive directions for the construction of Canoes, Rowing and Sailing Boats, and Hunting Craft. By W. P. STEPHENS. *With numerous illustrations and 24 plates of Working Drawings.* Crown 8vo, cloth, 7s. 6d.

Proceedings of the National Conference of Electricians, Philadelphia, October 8th to 13th, 1884. 18mo, cloth, 3s.

Dynamo - Electricity, its Generation, Application, Transmission, Storage, and Measurement. By G. B. PRESCOTT. *With 545 illustrations.* 8vo, cloth, 1l. 1s.

Domestic Electricity for Amateurs. Translated from the French of E. HOSPITALIER, Editor of "L'Electricien," by C. J. WHARTON, Assoc. Soc. Tel. Eng. *Numerous illustrations.* Demy 8vo, cloth, 9s.

CONTENTS:

1. Production of the Electric Current—2. Electric Bells—3. Automatic Alarms—4. Domestic Telephones—5. Electric Clocks—6. Electric Lighters—7. Domestic Electric Lighting—8. Domestic Application of the Electric Light—9. Electric Motors—10. Electrical Locomotion—11. Electrotyping, Plating, and Gilding—12. Electric Recreations—13. Various applications—Workshop of the Electrician.

Wrinkles in Electric Lighting. By VINCENT STEPHEN. *With illustrations.* 18mo, cloth, 2s. 6d.

CONTENTS:

1. The Electric Current and its production by Chemical means—2. Production of Electric Currents by Mechanical means—3. Dynamo-Electric Machines—4. Electric Lamps—5. Lead—6. Ship Lighting.

The Practical Flax Spinner; being a Description of the Growth, Manipulation, and Spinning of Flax and Tow. By LESLIE C. MARSHALL, of Belfast. *With illustrations.* 8vo, cloth, 15s.

Foundations and Foundation Walls for all classes of Buildings, Pile Driving, Building Stones and Bricks, Pier and Wall construction, Mortars, Limes, Cements, Concretes, Stuccos, &c. 64 *illustrations.* By G. T. POWELL and F. BAUMAN. 8vo, cloth, 10s. 6d.

Manual for Gas Engineering Students. By D. LEE. 18mo, cloth 1*s.*

Hydraulic Machinery, Past and Present. A Lecture delivered to the London and Suburban Railway Officials' Association. By H. ADAMS, Mem. Inst. C.E. *Folding plate.* 8vo, sewed, 1*s.*

Twenty Years with the Indicator. By THOMAS PRAY, Jun., C.E., M.E., Member of the American Society of Civil Engineers. 2 vols., royal 8vo, cloth, 12*s.* 6*d.*

Annual Statistical Report of the Secretary to the Members of the Iron and Steel Association on the Home and Foreign Iron and Steel Industries in 1884. Issued March 1885. 8vo, sewed, 5*s.*

Bad Drains, and How to Test them; with Notes on the Ventilation of Sewers, Drains, and Sanitary Fittings, and the Origin and Transmission of Zymotic Disease. By R. HARRIS REEVES. Crown 8vo, cloth, 3*s.* 6*d.*

Well Sinking. The modern practice of Sinking and Boring Wells, with geological considerations and examples of Wells. By ERNEST SPON, Assoc. Mem. Inst. C.E., Mem. Soc. Eng., and of the Franklin Inst., etc. Second edition, revised and enlarged. Crown 8vo, cloth, 10*s.* 6*d.*

Pneumatic Transmission of Messages and Parcels between Paris and London, viâ Calais and Dover. By J. B. BERLIER, C.E. Small folio, sewed, 6*d.*

List of Tests (Reagents), arranged in alphabetical order, according to the names of the originators. Designed especially for the convenient reference of Chemists, Pharmacists, and Scientists. By HANS M. WILDER. Crown 8vo, cloth, 4*s.* 6*d.*

Ten Years' Experience in Works of Intermittent Downward Filtration. By J. BAILEY DENTON, Mem. Inst. C.E. Second edition, with additions. Royal 8vo, sewed, 4*s.*

A Treatise on the Manufacture of Soap and Candles, Lubricants and Glycerin. By W. LANT CARPENTER, B.A., B.Sc. (late of Messrs. C. Thomas and Brothers, Bristol). *With illustrations.* Crown 8vo, cloth, 10*s.* 6*d.*

The Stability of Ships explained simply, and calculated by a new Graphic method. By J. C. SPENCE, M.I.N.A. 4to, sewed, 3*s.* 6*d.*

Steam Making, or Boiler Practice. By CHARLES A. SMITH, C.E. 8vo, cloth, 10*s.* 6*d.*

CONTENTS:

1. The Nature of Heat and the Properties of Steam—2. Combustion.—3. Externally Fired Stationary Boilers—4. Internally Fired Stationary Boilers—5. Internally Fired Portable Locomotive and Marine Boilers—6. Design, Construction, and Strength of Boilers—7. Proportions of Heating Surface, Economic Evaporation, Explosions—8. Miscellaneous Boilers, Choice of Boiler Fittings and Appurtenances.

The Fireman's Guide; a Handbook on the Care of Boilers. By TEKNOLOG, föreningen T. I. Stockholm. Translated from the third edition, and revised by KARL P. DAHLSTROM, M.E. Second edition. Fcap. 8vo, cloth, 2*s.*

A Treatise on Modern Steam Engines and Boilers, including Land Locomotive, and Marine Engines and Boilers, for the use of Students. By FREDERICK COLYER, M. Inst. C.E., Mem. Inst. M.E. *With* 36 *plates.* 4to, cloth, 25*s.*

CONTENTS:

1. Introduction—2. Original Engines—3. Boilers—4. High-Pressure Beam Engines—5. Cornish Beam Engines—6. Horizontal Engines—7. Oscillating Engines—8. Vertical High-Pressure Engines—9. Special Engines—10. Portable Engines—11. Locomotive Engines—12. Marine Engines.

Steam Engine Management; a Treatise on the Working and Management of Steam Boilers. By F. COLYER, M. Inst. C.E., Mem. Inst. M.E. 18mo, cloth, 2*s.*

Land Surveying on the Meridian and Perpendicular System. By WILLIAM PENMAN, C.E. 8vo, cloth, 8*s.* 6*d.*

The Topographer, his Instruments and Methods, designed for the use of Students, Amateur Photographers, Surveyors, Engineers, and all persons interested in the location and construction of works based upon Topography. *Illustrated with numerous plates, maps, and engravings.* By LEWIS M. HAUPT, A.M. 8vo, cloth, 18*s.*

A Text-Book of Tanning, embracing the Preparation of all kinds of Leather. By HARRY R. PROCTOR, F.C.S., of Low Lights Tanneries. *With illustrations.* Crown 8vo, cloth, 10*s.* 6*d.*

115